Transition from variable delay of reinforcement schedules to variable-time (VT) schedules of reinforcement. A systematic investigation.

Thesis

Transition from variable delay of reinforcement schedules to variable-time (VT) schedules of reinforcement. A systematic investigation.

by

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A thesis submitted to the Open University for the degree of Doctor of Philosophy in the discipline of Psychology.

July, 1984.

Date of submission: 31.7.84

Date of award: 11.12.84

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DEDICATION

This thesis is dedicated to my parents, Sidney and Marie Burgess, who taught me both a profound respect for the truth and that nothing was beyond question.

ABSTRACT

Six experiments are reported in which rats were trained under response-dependent reinforcement schedules prior to being transferred to variable-time (VT) schedules which were matched in terms of both the overall rate and temporal distribution of reinforcement to the prior response-dependent reinforcement schedule. The response-dependent reinforcement baseline schedules varied according to whether they permitted reinforcement delays or only allowed the designated response to be contiguous with the reinforcer. In addition, some of the baseline schedules required either 'other behaviour'-response or response-'other behaviour' sequences for reinforcement. The results indicated that delay of reinforcement schedules generally were associated with stronger resistance to response-independent reinforcement relative to immediate reinforcement schedules. Further, immediate reinforcement schedules which demanded 'other behaviour'-response sequences for reinforcement tended to produce stronger resistance to response-independent reinforcement than those which permitted more than one response class to occur, but only required the emission of the designated operant for reinforcement. Rate of responding, level of efficiency of responding and postreinforcement pause duration during the baseline were poor predictors of response persistence during VT schedules. Response rate during the VT schedules was inversely related to mean delay of reinforcement (experiments IV and VI), while response decrement was related to the proportion of interreinforcement intervals without a response (experiments I, II,III, IV, V and VI). Reinforced and

overall interresponse time (IRT) distributions during the VT condition were significantly correlated; further, changes in response rate were reflected in changes in the IRT distributions. It was concluded that an analysis of response maintenance under VT schedules which is framed in terms of the discrimination of response-reinforcer correlations was not supported. It was proposed that a molecular theory in which IRT-reinforcer contiguities are emphasized probably holds more promise.

DECLARATION

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification to this or any other university or institute of learning.

PUBLISHED WORK

The following papers include data from some of the experiments reported herein.

Burgess, I.S. Resistance to response-independent reinforcement produced by different schedules of reinforcement: Ratio versus interval schedules. In Bradshaw, C.M., Szabadi, E. and Lowe, C.F. Quantification of Steady-State Operant Behaviour. Amsterdam. Biomedical Press. 1981.

Burgess, I.S. and Wearden, J.H. Resistance to the response-decrementing effects of response-independent reinforcement produced by delay and non-delay schedules of reinforcement. Quarterly Journal of Experimental Psychology 1981,33B,195-207.

Burgess, I.S. and Wright, J.E. Resistance to variable-time schedules produced by spaced-response reinforcement schedules. Behaviour Processes in press.

ACKNOWLEDGEMENTS

I would like to thank my supervisor, Jim Wright, for all the assistance he has given me over the years as well as sharing his laboratory facilities with me so that experiments III, IV and VI could be carried out.

Linda Hunt for assistance with matters statistical - thank you. For putting up with and believing in me during the year of my writing up - a heartfelt and grateful thank you!

To John Wearden for his unflagging enthusiasm for the area of the experimental analysis of behaviour and in particular his interest in the field of response-independent reinforcement.

To Bob MacArthur with whom I shared a house during my stay in Leeds, thanks for the good times. Grateful thanks also to Lizanne Dowds (now MacArthur).

Thanks to the members of the Dept. of Psychology, University of Leeds who made me so welcome during my two terms there. A special thanks to Andy for all the discussions we had about cricket.

I would also like to thank Peter, John and Eric, the technicians in the School of Psychology, Manchester Polytechnic who performed near miracles in keeping the apparatus running. To Ian Reid for his invaluable assistance and advice concerning preparation of diagrams, as well as his 'Scouse' sense of humour.

Other individuals have provided welcome distractions during the conduct of the work for this thesis. They are too numerous to mention here - but recognition is gratefully given.

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CHAPTER 1 INTRODUCTION

"There are two fundamental cases: in one the reinforcing stimulus is correlated temporally with the response . . . For 'correlated with' we might write 'contingent upon'." (Skinner, 1937)

The conditioned response of Type I does not prepare for the reinforcing stimulus, it produces it." (Skinner, 1935)

"The experiment might be said to demonstrate a sort of superstition. The bird behaves as if there were a causal relation between its behaviour and the presentation of food, although such a relation is lacking." (Skinner, 1948)

"The response produces food only in the sense that food follows it." (Skinner, 1966).

1.1. General Introduction

The notion that events will become associated with each other if they occur closely together in time has formed one of the cornerstones of behaviour theory. Such a view predates academic Psychology by many centuries. The importance of contiguity between events as a determinant of their becoming associated with each other can be traced back to the writings of Aristotle (Wolman, 1960). Temporal contiguity, however, attained its influential role in the philosophical literature when it was used as part of the

armoury of the British empiricists in their attempted refutation of the nativist ideas of the Cartesians. In modern experimental psychology, the importance of temporal contiguity between either stimuli or stimulus and response has found its metier in conceptualizations of conditioning phenomena, both classical and operant (instrumental) (Gormezano and Kehoe, 1981; Hilgard, 1948)

Both Pavlov and Thorndike (see Hilgard, 1948) emphasized the role of temporal contiguity in their formulations of conditioning. Thorndike is particularly clear about this in his Law of Effect. "Of several response made to the same situation, those which are accompanied or closely followed by satisfaction to the animal, will, other things being equal, be more firmly connected with the situation, so that, when it recurs, they will be more likely to recur; those which are accompanied or closely followed by discomfort to the animal will, other things being equal, have their connections with that situation weakened, so that, when it recurs, they will be less likely to occur. The greater the satisfaction or discomfort, the greater the strengthening or weakening of the bond." (Thorndike, 1911, p244 my emphasis).

Such was the perceived importance of temporal contiguity in learning, that delay of reinforcement was accorded a major role as a determinant of response strength in various neobehaviourist systems (e.g. Capaldi, 1971; Hull, 1952; Spence, 1956).

1.2. Temporal Contiguity in Classical Conditioning

Since Pavlov's (1927) writings, the temporal relationship between the conditioned stimulus (CS) and the unconditioned stimulus (US) has been emphasized as being one of the major sources of the strength of the eventual conditioned response (CR). There is little doubt that the delayed conditioning arrangement in which the onset of the CS predates the onset of the US but both end coterminously, yields the strongest conditioning (Mackintosh, 1974). It is possible to obtain excitatory simultaneous, trace and backward conditioning but these temporal arrangements do not produce as strong a CR as either delayed or forward conditioning (Kamin, 1965; Mahoney and Ayres, 1976; Rescorla, 1981; Wagner and Terry, 1975). Lengthening the interval between CS offset and US onset (trace conditioning) or exposing the organism to over 20 presentations of the CS and US in both simultaneous and backward arrangements can result in the CS becoming either neutral (i.e., losing strength) or even inhibitory (Hinson and Siegel, 1980; Heth, 1976). Yet the role of temporal contiguity within classical conditioning has had a controversial history.

In a seminal article, Rescorla (1967) argued that the major determinant of performance changes in classical conditioning was the molar correlation or contingency between the CS and US, rather than individually occurring contiguities. He reports an experiment in which the probability of US presentation was varied in both the presence and absence of the CS (Rescorla, 1972). The arrangement in which the US

presentation was equally likely in both CS presence and absence (the truly random control procedure - TRC) yielded a CS with no apparent associative strength. At first sight such a finding appears to be an embarrassment for the contiguity position. Both subsequent evidence and theorising, however, reveal that Rescorla's (1967) view is probably an oversimplification. For example, the TRC does not leave a CS neutral because both subsequent excitatory and inhibitory conditioning of it are retarded (Baker and Mackintosh, 1977; Wasserman, Deich, Hunter and Nagamatsu, 1977). In addition, it is possible for a CS presented in a truly random fashion with respect to US presentation to acquire excitatory strength, the effect depending upon the timing and number of chance pairings between the CS and US (Keller, Ayres and Mahoney, 1977). This result can be derived from the Rescorla and Wagner (1972) mathematical model, which is a contiguity based formulation. Possibly more damaging to a simple correlation view is the research and theorising on compound conditioning, and, more especially on the phenomenon known as blocking (Kamin, 1969; Rescorla and Wagner, 1972). That research reveals that the loss of strength of a CS in the TRC can be adequately explained as an example of context blocking (Hinson, 1982; Kremer, Specht and Allen, 1980; Tomie, Hayden and Biehl, 1980). The US-preexposure effect also provides support for the context blocking (or contiguity) account (Balsam and Schwartz, 1981; Randich and LoLordo, 1979). Therefore, within the context of stimulus selection, both cognitive and associationist theorists agree that temporal contiguity

between CS and US is crucial (e.g., Mackintosh, 1975; Rescorla and Wagner, 1972).

Related to the correlation issue was the attack made upon contiguity theory by those theorists who preferred an informational account. This view gained its impetus from an experiment reported by Egger and Miller (1962). In that experiment, 2 CSs were presented serially before US presentation. It was found that the first CS in the series acquired more associative strength relative to the second CS despite being further temporally removed from the US. It seemed that the initial CS was more informative, or that the second CS was redundant in the sense of signalling the impending US. Later experimentation has demonstrated that the Egger and Miller procedure is probably flawed (Gormezano and Kehoe, 1981, pp26-7). The informational hypothesis also experiences problems in explaining how both a simultaneous and backward arrangement of CS and US can result in excitatory conditioning (Heth, 1976; Rescorla, 1981; Wagner and Terry, 1975). Results such as these have led Rescorla to conclude that the informational hypothesis ". . . is incomplete and incorrect." (Rescorla, 1972, p43).

Thus, although temporal contiguity has had its more delicate moments, and a strict Law of Contiguity is probably untenable, a more liberal version is still viable within the classical conditioning field (Gormezano and Kehoe, 1975;1981).

1.3. Operant Conditioning - Some Persistent Issues

1.3.1. Contingency and Contiguity in Operant Conditioning

Skinner's use of the word 'contingent' to describe the relationship between a response and a reinforcer in operant conditioning has not always been consistent. This inconsistency has led to some confusion in the operant conditioning literature especially concerning the necessary conditions which must exist before a change in behaviour can be classified as being an example of operant conditioning. The confusion probably arose out of Skinner's (1935;1937) early papers. In discussing the differences between operant and classical conditioning (Types I and II respectively) he noted that "The conditioned response of Type I does not prepare for the reinforcing stimulus, it produces it." (Skinner, 1935, reprinted 1972, p487, my emphasis). This statement seems to imply that there is a causal or procurement relationship between responding and reinforcement in operant conditioning (Schoenfeld and Cole, 1972). Yet in a subsequent article, Skinner states that "There are two fundamental cases: in one the reinforcing stimulus is correlated temporally with a response . . . For 'correlated with' we might write 'contingent upon'." (Skinner, 1937, reprinted 1972, p490). Correlations are not causes; in fact there need to be no dependency underlying a correlation between two events. The correlation could be due to chance or that the two events in question are dependent upon a third event which is the 'true' cause.

Despite this confusion, 'contingency' has become one of the

cornerstones of operant conditioning (Schoenfeld and Farmer, 1970). The idea that contingency denotes a causal relationship between responding and reinforcement, however, was questioned by Skinner's (1948) demonstration of 'superstitious conditioning'. In that experiment, Skinner allowed pigeons brief access to food on a periodic schedule (fixed-time 15secs - FT15) irrespective of their behaviour. It became clear that this procedure induced stereotyped behavioural sequences in the pigeons. Further, these sequences could be extinguished by omitting food presentations. Skinner noted that "The bird behaves as if there were a causal relation between its behaviour and the presentation of food, although such a relation is lacking." (Skinner, 1948, p171). Here reinforcement was 'noncontingent' in the sense that it was not related to a predesignated response, yet the behaviour of the organism was significantly altered. Skinner's results have been replicated with both pigeons and other organisms (rats and children) (Davis and Hubbard, 1972; Fenner, 1980; Staddon and Ayres, 1975; Staddon and Simmelhag, 1971; Zeiler, 1972). Some of these writers have questioned Skinner's interpretation (Staddon and Simmelhag, 1971) but all agree that allowing a known reinforcer to freely enter the behaviour stream affects the behaviour of the organism. Whatever interpretation is given to this phenomenon, two observations are justified. First, a behavioural sequence is acquired, and, second, this sequence is maintained in this experimental situation. It therefore becomes clear that a programmed contingency or dependency between a

response and a reinforcer is not necessary for either the acquisition or maintenance of behavioural unit.

In considering the implications of superstitious conditioning for operant conditioning in general, Skinner shows a certain degree of ambivalence. Consider the following two quotations:

"To say that a reinforcement is contingent upon a response may mean nothing more than that it follows the response. It may follow because of some mechanical connection or because of the mediation of another organism; but conditioning takes place presumably because of the temporal relation only, expressed in terms of the order and proximity of response and reinforcement." (Skinner, 1948, p168, my emphasis).

"It is perhaps not quite correct to say that conditioned behaviour has been set up without any previously determined contingency whatsoever. We have appealed to a uniform sequence of responses in the behaviour of the pigeon to obtain an overall net contingency. (Skinner, 1948, p171, my emphasis).

From the initial quotation there is no mention of the procurement relationship mentioned in his 1935 paper; in the latter quotation, however, a new distinction appears to be emerging, i.e., between an experimenter-imposed contingency and an 'effective' contingency. In a still later paper, Skinner seems to have reduced the causal aspect of contingency, "The response produces food only in the sense that food follows it." (Skinner, 1966, p14). This set of quotations reveals that Skinner believes that contingencies

are always present, whether programmed by the experimenter or not. This brings the notion of contingency very close to a contiguity construct, for the defining characteristic appears to be the temporal relation between the response and the reinforcer (Skinner, 1948).

A number of experimental analysts of behaviour have attempted to define or redefine contingency. Some of these attempts will now be analysed.

1.3.1.1. Schoenfeld's view

Schoenfeld and his colleagues (Schoenfeld and Farmer, 1970; Schoenfeld, Cole, Lang and Mankoff, 1973) have attempted to define contingency within a set of temporal parameters. They have proposed two definitions of contingency:

A contingency between a response and reinforcement exists when " . . . the distribution in time of R (response) determines the distribution in time of reinforcements; while by the opposed token, noncontingency means that the temporal distribution of reinforcements is not determined by the temporal distribution of responses. When we speak here of 'noncontingent reinforcement', we shall mean a stimulus which, if we applied it contingently to R - that is, in such a way that its temporal distribution is determined by R's temporal distribution - would have the effect upon R that is called 'reinforcing'." (Schoenfeld and Farmer, 1970, p221).

Contingency " . . . is any rule by which an experimenter imposes a conditional probability between R and SR (reinforcement) in that temporal sequence, and thereby

forces a dependence of the distribution of SRs in time upon the distribution of Rs in time."

(Schoenfeld, Cole, Lang and Mankoff, 1973, p153).

The distinction here then is simply the presence of an experimenter-imposed dependency. Schoenfeld and his colleagues argue for the dismissal of the notion of contingency from operant terminology. The efficiency of a contingency is, according to their view, mediated by the contiguities that it guarantees (on basic schedules, at least). Therefore, it can be replaced by a consideration of the contiguities that take place between, on the one hand, the designated response and the reinforcer, and, on the other, other behaviour and the reinforcer. It is clear that Schoenfeld's view does not depart a great deal from Skinner's although they are critical of Skinner's failure to reject the notion of a contingency as being necessary for operant conditioning (Schoenfeld et al, 1973). Contingency, on the Schoenfeldian view, becomes a special case of contiguity.

1.3.1.2. The Davis-Hubbard Position

In the discussion of their research on superstitious behaviour in the rat, Davis and Hubbard (1972) consider the similarities and differences between contingency and contiguity. They propose that contingency is a dichotomous variable being best described as a conditional implication (if-then relationship). Contiguity, on the other hand, is a continuous variable. They note that while contingency may be necessary to maintain a behaviour, its ability to do so

is determined by the fact that it guarantees reliable contiguities between the behaviour and the reinforcer. Such a view, however, assumes that only immediate reinforcement schedules are used, or that delay of reinforcement produces less response strength. Although this is generally true when rate of responding is the criterion (but see Sizemore and Lattal, 1978 for an exception), other measures of response strength such as resistance to extinction, must cast some doubt on their position (Mackintosh, 1974). Although Davis and Hubbard (1972) emphasize the difference between contingency and contiguity, they do note that contingency can only be experienced by the organism as a series of contiguities.

1.3.1.3. Zeiler's Position

Zeiler (1972) notes that at least two uses of contingency are obvious in the experimental analysis of behaviour literature. The first is where contingency is used as an independent variable. In this case it is synonymous with the notion of schedule, i.e., it states the rule under which reinforcement will be dispensed. Contingency therefore states the necessary conditions which have to obtain if a reinforcer is to be permitted to enter the behaviour stream. Under this characterization, it is impossible to ever have a noncontingent schedule (see also Schoenfeld and Farmer, 1970), because reinforcement is, at the very least, contingent upon time. Zeiler's (1972) solution here is to replace contingency with a new distinction, viz., that between response dependency and response independence. The

second use of contingency is where it is cast in the role of a dependent variable. In this case, contingency refers to all of the behaviour that precedes reinforcement. This includes behaviour which is required for reinforcement as well as that which is not. Thus, in the example of a fixed-interval (FI) schedule, only 1 response per reinforcer is actually required. Yet it is typical under such schedules for more than 1 response to occur, further, these usually take a particular stereotyped form, viz., the scallop (Dews, 1970; 1978). The term contingency here would refer to the whole scallop. Under this usage, the term contingency also loses any sense because, once more, noncontingency is impossible to achieve, since some behaviour must occur between reinforcers. According to Zeiler "A schedule may or may not involve a response dependency, but all involve contingencies." (Zeiler, 1972, p6). In agreement with Schoenfeld et al (1973), Zeiler maintains that "research . . . suggests that the essential nature of the response-reinforcer relation is temporal . . ." (Zeiler, 1977a, p204).

This discussion reveals that there is some degree of agreement between the various writers on this topic. Schoenfeld et al's (1973) distinction between contingency and noncontingency is very similar to Zeiler's (1972) use of the response dependency/independency characterization. Davis and Hubbard's (1972) view is also similar to Zeiler's first usage of contingency. Skinner's (1948) position seems closer to Zeiler's second use. The view accepted here will

be to reject the use of the term contingent in favour of response dependent/independent.

1.3.2. Operant Conditioning - The Response Unit Problem

Central to the phenomenon of operant conditioning is the idea that behaviour is continuous (Schoenfeld et al, 1973). The concept of a behaviour stream, however, creates problems of measurement. If behaviour is continuous how does one identify the different elements which constitute it? Which should be monitored, and which can be safely ignored?

Finally, once a behaviour has been identified, along which dimensions should it be measured? Skinner was aware of these problems and proposed a number of solutions (Skinner, 1935;1937:1957). For Skinner, the response should have the following properties " . . . it should be easily observed, affect the environment in such a way that it can be easily recorded . . . and may be repeated many times without fatigue." (Skinner, 1957, reprinted 1972, p126). Further, the response has a generic character (Skinner, 1935). That is, operants are classes of responses all of which have a similar effect. For example, it is immaterial whether a rat presses the lever with either its right or left paw, as long as the lever depression closes a relay which will advance a counter by 1 unit. Lever presses which do not close the relay, do not count - thus topography is primarily irrelevant (Skinner, 1935). Operant behaviour is measured along the dimension of rate of occurrence. Rate is measured in two ways. The first is in terms of the cumulative record

and the second is in terms of the number of responses per unit of time (Skinner, 1937; 1966; 1976). Both of these measures were designed to assess probability of responding - albeit indirectly. Interestingly, these two measures would characterize Skinner as a mixed molar-molecular theorist, if contemporary terminology were to be applied. The use of overall rate of responding places him firmly in the molar camp (Baum, 1973) while his insistence on identifying individual responses and his advocacy of the use of cumulative records to examine local changes assigns him to the molecular camp (Williams, 1983). Both of these stances have been further analysed by experimental analysts of behaviour.

1.3.2.1. The Molecular View

There are several variants of this view; we shall review two of them.

1.3.2.1.1. Schoenfield's Position

Schoenfeld and Farmer (1970) have suggested that the behaviour stream can be divided into 2 mutually exclusive categories. These are designated as instances of the response (R) which is defined in much the same terms as Skinner (1957) had suggested; and, all other behaviour, which Schoenfeld and Farmer (1970) call not-responding or $\bar{R}$. $\bar{R}$ is defined along the temporal demension, i.e., absence of R for some specified period of time. Responding therefore exists in a context of $\bar{R}$. $\bar{R}$ can be reinforced, as is the case on the various spaced-response kind of schedules.

Given this type of definition, it is possible to have an infinite number of $\not R$ categories. Where both R and $\not R$ are being reinforced, the behaviour stream is split into 3 divisions. These are R occurrences, $\not R$ occurrences of the specified duration and any other duration of $\not R$. Schoenfeld and Farmer (1970) maintain that R and $\not R$ interact in complex ways to yield the behaviour stream. This interaction can be most clearly seen in those schedules which demand the occurrence of both classes (e.g., differential reinforcement of low rates or differential reinforcement of other behaviour schedules - DRL and DRO respectively). Schoenfeld and Farmer (1970) argue that such interactions take place even on those schedules where both R and $\not R$ are free to vary (response-independent schedules) or where only R-occurrences are demanded (ratio or interval schedules). There is no doubt that Schoenfeld and Farmer's (1970) division of the behaviour stream has proved heuristic (see Schoenfeld and Farmer, 1970). A number of problems, however, do arise. There are, for example, no general guiding principles as to the optimum duration of $\not R$. This is especially serious in those experimental contexts where either R is not reinforced or no criterion is set for it. Another problem is the topographical variations which may characterize $\not R$ - do they all have equal behavioural significance? The spatial relations of $\not R$ are also of interest. For example, if a rat spends most of its time during the emission of R at the back of the Skinner box, is this equivalent to a similar period of time spent near the lever or in the proximity of the food tray? Clearly on response-independent schedules, such a

difference could be crucial. Schoenfeld and Farmer (1970) are aware of the unsatisfactory nature of a simple temporal definition of t. Nevertheless, this view has proved heuristic in a number of contexts. It has certainly led to some interesting predictions concerning the action of response-independent reinforcement (Schoenfeld et al, 1973 - see also section 2.6.1.). By its emphasis on response interactions, it has provided an extra dimension to Skinner's description. Recently, it has been developed at a more molecular level by Henton and Iversen (1978).

1.3.2.1.2 Shimp's Position

A related but different sort of approach is that proposed by Shimp (Shimp, 1975; 1978). His views have two main objects of focus. First, his rejection of a simple contiguity view, that reinforcement serves to strengthen the response with which it is contiguous (e.g., Hawkes and Shimp, 1975). In the place of contiguity, Shimp has substituted a short term memory concept (Shimp, 1976). His second major theoretical point is that local effects of reinforcement are the prime determiners of responding. This view is in opposition to more molar approaches. Shimp (1975) maintains that molar relations, e.g., matching, can be reduced to a series of local, molecular, effects. Shimp (1975) has objected to the use of overall rate of response type measures on the ground that they ignore any patterning which might occur. For example, it is quite possible to use schedules such as a variable interval (VI) and a FI and obtain similar overall rates of responding. Yet cumulative records of the

behaviour under each schedule would reveal quite different patterns of responding, i.e., the schedules induce different temporal distributions of responses. It is Shimp's view that these patterns can form units of behaviour. In order to quantify them, he has suggested using the interresponse time (IRT) measure pioneered by Anger (1956). His view (Shimp, 1975) is that the IRT distribution is a sort of speeded up cumulative record (although of course it lacks the sequential characteristics of a cumulative record). The use of IRT distributions allows the experimental analyst of behaviour to examine the fine structure of behaviour as well as its functional determinants. Shimp's experiments do reveal that different sequences of behaviour can be conditioned, and these can function as behavioural units (Hawkes and Shimp, 1975). The patterns are defined by the IRT characteristics of the unit. In a sense, this approach is an extension of the spaced-response schedule (a series of tandem DRL schedules). There is no attempt to specify the topography of the behaviours which intervene between the emissions of the designated response (this is hardly surprising given the view that the behavioural unit is an IRT). To the extent that both Schoenfeld and Shimp emphasize local effects, so they are similar to each other. There are major differences between them, however. For example, Shimp has recently become much more cognitively oriented (Shimp, 1976; 1978), while Schoenfeld eschews such an approach (Schoenfeld and Cole, 1972). Shimp (1978) has recently adopted the computer simulation approach while Schoenfeld has not. Finally, Schoenfeld has consistently

occupied a strong contiguity position, while Shimp has directly opposed such a view (Shimp, 1978). Shimp's molecular approach has found some support (e.g., Silberberg, Hamilton, Ziriax and Casey, 1978). There is also some evidence to suggest that reinforcement often produces stereotyped patterns of behaviour, even when other patterns are available (Schwartz, 1981). Dews (1970) has shown that the 'scallop' on FI schedules can function as a response unit. Much of the research supporting Shimp, however, has emerged from studies in which highly constrained schedules (Zeiler, 1979a) were used. There is no guarantee, however, that, when these constraints are withdrawn, the behaviour which emerges is still determined by similar variables. Thus, the pattern and rates of responding observed under conventional schedules may not be mediated by the selective reinforcement of different IRTs (Marr, 1979). Because a unit of behaviour is conditionable, and that unit can be adventitiously reinforced on conventional schedules, does not mean that it necessarily mediates behaviour (Zeiler, 1977a).

Nevertheless, Shimp's view has focused attention on the structure of behaviour and there is no doubt of its influence in contemporary experimental analysis.

1.3.2.2. The Molar Position

One of the major developments in the experimental analysis of behaviour over the last 20 years has been the emergence of molar theory (Williams, 1983). Molar theory received its main impetus from the research conducted by Herrnstein

(Herrnstein, 1970). In his seminal article, Herrnstein (1970) was able to demonstrate that relative response rate was a hyperbolic function of relative reinforcement rate on both single and concurrent VI schedules. This relationship, which is linear when expressed in logarithmic coordinates, has become known as Herrnstein's equation for single schedule situations and the matching law for concurrent schedule situations. Although several changes have been made to the matching law (e.g., Baum, 1974), it has proved to be remarkably robust (Wearden and Burgess, 1982).

Molar theory has several characteristics which differentiate it from the more traditional view as espoused by Skinner (1935; 1937). The first difference relates to the type of behaviour examined. Whereas Skinner was interested in both acquisition (including transitional states) and maintenance of behavioural episodes, molar theorists concentrate almost entirely upon steady-state behaviour. This has resulted in a change in the way probability of responding is viewed. From the traditional viewpoint, experimental analysts of behaviour were concerned with two kinds of probability of responding, viz., momentary and overall probability. Molar theorists focus their attention on the latter. Baum has noted that " . . . variation in measures like average response rate . . . cannot be assessed at any moment and hence are referred to as molar." (Baum, 1981, p247); and again "Since it (response frequency) transcends instances of discrete responses it can be called a molar variable that enters into a molar relation (correlation) with another

molar variable, the consequence . . ." (Baum, 1973, p148). Molar theorists object to the view that the type of response-reinforcement relations which they study can be reduced to a series of molecular or local relationships. In fact, molecular relations are regarded as being 'noisy'. The molar-molecular clash has become one of the major controversies in the experimental analysis of behaviour, although some rapproachment is becoming evident (Baum, 1981; Nevin, 1979a; 1982; Shimp, 1975; Silberberg et al, 1978; Timberlake, 1982).

Molar theorists have also objected to the central role given to temporal contiguity. In its place they have suggested using a correlation type of mechanism which is not dissimilar to the one proposed by Rescorla (1967) (see section 1.2.). "The correlation-based law of effect suggests that simple response-reinforcer contiguity cannot account for instrumental behaviour - that the molar relation between responding and reinforcement is crucial. It does imply a role for contiguity, however, . . . Response-reinforcement contiguity . . . ensures a good correlation between output and feedback." (Baum, 1973, pp141 and 145). Molar theory has been one of the major explanations of the effects of response-independent reinforcement.

Molar theorists have made a major contribution to response measurement. Although they sometimes use absolute rate measures, more often than not they have tended to use relative measures. This strategy has made good sense in

contexts where more than one schedule has been operative, for it allows for direct comparisons across schedule conditions within and between experiments. It also emphasizes reinforcement interactions. In addition to using relative response rate measures, they have also pioneered the use of time allocation (but see Skinner, 1950). Time allocation is the amount of time an organism spends emitting a response during a session; or the amount of time it spends in the presence of one of a series of alternatives. Relative time allocation is taken as a measure of the value of the alternative (Baum and Rachlin, 1969). Evidence from the concurrent reinforcement literature reveals that time allocation is a more sensitive measure to changes in reinforcement rates when compared with relative response rate measures (Wearden and Burgess, 1982). Recent evidence from single schedule situations supports that conclusion (Pear and Rector, 1979; Pear, Rector and Legris, 1981). Although using different size units it can be seen that such a measure does bear a resemblance to Schoenfeld and Farmer's (1970) division of the behaviour stream (R in the molar situation would be accounted for by Herrnstein's concept of r_e).

Thus Skinner's insistence on the primacy of absolute rates and the use of cumulative records is now more open to question. In the experiments to be reported here, a variety of measures were used, depending upon the aim of the experiment (Zeiler, 1979a).

CHAPTER 2 REVIEW OF THE LITERATURE

2.1. Introduction

This review begins with a consideration of the research in which a known reinforcer is allowed to freely enter the behaviour stream ('the superstitious conditioning' effect). This is followed by an examination of those cases where an organism is transferred from a response-dependent reinforcement baseline to a response-independent reinforcement schedule; as well as experiments where a response-independent reinforcement schedule is superimposed upon a response-dependent reinforcement baseline. Finally, two theoretical views concerning the effects of response-independent reinforcers are examined.

2.2. Superstitious Conditioning

According to some theorists, the term 'conditioning' in the context of adventitious reinforcement is inappropriate (Staddon and Simmelhag, 1971). There is good reason to doubt that view as the following review will demonstrate. The first study to be reported in this field was that conducted by Skinner (1948). Skinner's (1948) experiment is rather casually reported. It was a deceptively simple experiment. Food-deprived pigeons were exposed to periodic deliveries of food independently of their behaviour. When exposed to such a schedule (a fixed-time schedule), the birds usually developed a stereotyped form of behaviour. The topography of the behaviour varied from bird to bird; however, six of the eight birds studied developed quite striking behaviours which " . . . were so clearly defined

that two observers could agree perfectly in counting instances." (Skinner, 1948, p168). The responses which increased in frequency tended to be directed towards some part of the environment, rather than being simply a series of movements. According to Skinner (1948), the independent variable responsible for this effect was the duration of the interreinforcement interval (IRI). With a relatively brief interval (e.g., 15sec), it is probable that behaviour of a similar topography will continue to be contiguous with the reinforcer. When the IRI is increased, however, a drift in topography is more likely to occur and the effect will be lost. In his initial demonstration, Skinner (1948) used an IRI of 15sec, the effect was much less stable when he began the experiment with an IRI of 60sec. He was able to demonstrate that the stereotyped behaviours could be maintained at intervals longer than 15sec, if the IRI was gradually lengthened. Skinner (1948) made a number of other interesting observations. First, the response which comes to dominate the behaviour stream, appears to be under temporal control. For example, a stepping response which could be automatically recorded, was observed in one bird. The cumulative record of this response was scalloped "The record . . . resembles in every respect the characteristic curve for the pigeon under fixed-interval reinforcement of a standard selected response." (Skinner, 1948, p170). Second, it was possible to extinguish such a response using the conventional procedure (reinforcement omission). The behaviour which emerged under these conditions appeared to behave in a fashion similar to a conventional operant.

Although the 'superstitious conditioning' phenomenon became a general laboratory demonstration, it was some time before it was systematically examined. Several replications have appeared in the literature. These have paid more attention to experimental detail than is apparent from Skinner's (1948) original report. For example, it is not clear from Skinner's (1948) paper how many sessions the birds were given; nor is any mention made of session duration. Further, Skinner (1948) reports using only fixed-time schedules (FT). A natural question seems to be whether the same effects would be obtained if reinforcements were dispensed at variable times (variable-time schedules - VT). Later experiments have provided more detailed expositions.

Probably the most comprehensive examination of superstitious conditioning was that reported by Staddon and Simmelhag (1971). They used pigeons as subjects, and compared the behaviours emitted under 3 conditions - FT 12sec, FI 12sec and VT 8sec. The birds received between 26 and 111 sessions under each schedule, and behaviour was scored according to a pre-arranged system. Staddon and Simmelhag (1971) therefore, were able to examine both acquisition of behaviours and steady-state performance. They presented their results according to two schema. The first was in terms of the probability of occurrence of a behaviour as a function of time since reinforcement, while the second presented details of the sequential structure of behaviour. Staddon and Simmelhag (1971) were able to identify two kinds

of behaviour. These were interim behaviours and terminal behaviours. Interim activities were those responses which occurred at the beginning of an IRI and were rarely contiguous with the 'reinforcer'. Terminal behaviours replaced interim activities, and once initiated were maintained until the food was presented. Typically, they began at about 6-8 sec after food delivery on the VT schedule. At steady-state it was rare for the terminal response to be of the same topography as the behaviours which Skinner (1948) had observed. Terminal behaviours tended to be either some kind of pecking response or an orientation towards the magazine wall i.e. they were food-related behaviour. Occasionally, other behaviours, e.g., head in the magazine or 'dizzy motion', did take on terminal behaviour characteristics. The behaviours which Skinner (1948) had observed tended to be interim activities. In terms of acquisition, it appears that the final topography of the terminal response emerged by about the eigth session. Prior to that, other behaviours occurred at reinforcement, the most prevalent of these being 'head in the magazine', for the bird described by Staddon and Simmelhag (1971). The only differences between the schedules were that the terminal behaviour emerged earlier during the IRI on the VT schedules relative to both the FI and FT schedules, and pecking was directed at a smaller area (the key) under the FI schedule relative to the FT schedules. Pecking rates, however, did not differ between either the FT or FI schedules. The sequential data supported these trends. Essentially, a small number of sequences of behaviour were

acquired, such sequencing was rigid, and any variability which did take place tended to happen early in the interval (i.e., during the emission of interim activities).

Staddon and Simmelhag (1971) present a series of complex arguments concerning these findings. The details of their view go beyond the scope of this review; however, some of the general points they make are worth considering. They reject Skinner's (1948) contiguity based view as being too simplistic. They suggest that the emergence and maintenance of behaviours observed in this kind of experimental situation can be explained by two sets of principles. These are the principles of behavioural variation and the principles of reinforcement. Generally, the former are responsible for the emergence of a behaviour, while the latter describe the action of a reinforcer in the normal operant conditioning situation. They propose that reinforcers, rather than strengthening a behaviour, are selective in the sense that they eliminate behaviours from the behaviour stream. It is their view that the term adventitious reinforcement has little, if any, conceptual worth. The reason for this is that a reinforcer can only be selective if there is some imposed contingency/dependency between some aspect of behaviour and that reinforcing stimulus. Further, the dependency must be permitted to contact the appropriate behavioural unit. Such a view is close to the molar position advanced by Herrnstein (1970) and Baum (1973). If the principles of reinforcement have no role to play in the present experimental situation (because

there is no response-reinforcer dependency, at least in the case of the FT and VT schedules) the question which arises is how does the terminal behaviour emerge? And once present, how is it maintained? The reply made by Staddon and Simmelhag (1971) is that both are determined by the principles of behavioural variation. Terminal behaviour is maintained by the induction of a motivational state which corresponds to the reinforcer. This state is responsible for the elicitation of behaviours which become probable when the reinforcer becomes due. The time course of pecking observed under the VT schedule is a case in point. Here, interim behaviours occupied the first 2 sec of the IRI. Since the shortest interval on the VT schedule used by Staddon and Simmelhag (1971) was 3 sec, the momentary probability of food presentation began to increase and this was correlated with an increase in the probability of the emission of the terminal behaviour. A similar case can be made for the time course of the behaviours which emerged under the FT schedule; although there might be reason to implicate a Pavlovian conditioning mechanism in this case (temporal conditioning). In a later experiment, Staddon and Ayres (1975) demonstrated that post-food time as well as probability of reinforcement is also an important determinant of behaviour in this kind of experimental situation.

In an attempt to estimate the power of these variables, Fenner (1980) has repeated Staddon and Simmelhag's (1971) experiment. Although some of his data support their

conclusions, other data conflict with their results. The major disagreement between the studies is that Fenner (1980) found a consistent discrepancy between the rate of pecking supported by the response-dependent and response-independent schedules. The former maintained a much higher rate. Staddon and Simmelhag (1971) found no difference between the schedules in terms of rate of pecking. Fenner (1980) also observed different terminal responses. For example, under the FT schedule 'pecking the magazine wall' and 'body facing the magazine wall' both had the characteristics of a terminal response. On a random-time schedule (RT - in which probability of reinforcement remains constant from moment to moment) the following behaviours emerged as terminal responses 'body facing magazine wall', 'body facing any other wall' and 'hopping/stepping'. The interim behaviours which emerged under the FT schedule were 'body facing magazine and other walls' and 'stepping'. On the RT schedule only 'body facing magazine wall' emerged as an interim behaviour, and that only in 3 out of 12 cases. Of the remainder, it showed either a mixed terminal/interim pattern (2 cases) or a constant probability pattern (7 cases), i.e., controlled by the momentary probability of reinforcement. Fenner (1980) concludes that the behaviours which emerge under response-independent reinforcement are controlled by both the momentary probability of food and post-food time. It is clear then that some of the behaviours which Skinner (1948) observed can function as terminal behaviours, even under steady-state. Such behaviours (e.g., hopping under RT schedules) are not

intuitively food-related behaviours.

Davis and Hubbard (1972) have examined the behaviour of rats when the schedules were FT15, 30 and 60 sec and VT 15, 30 and 60 sec. Subjects were exposed to one of these conditions (3 rats per group) for 8 sessions prior to being exposed to extinction. There were also 2 control subjects who never received food in the experimental situation. They found that stereotyped behaviours emerged under both the FT and VT conditions. These behaviours were induced more quickly under the FT schedules relative to the VT schedules, irrespective of duration of the IRI. Typical behaviours which emerged under the FT schedules were either facing the food tray or moving towards it. Such behaviours were most likely to take place near the end of the IRI. This kind of behaviour can be seen as an example of a terminal behaviour according to Staddon and Simmelhag's (1971) scheme. The rats in the FT15 sec condition were more active than the rats in the other FT conditions. Davis and Hubbard (1972) also report the emergence of other behaviours such as circling, sniffing and nosing which might be regarded as interim behaviours, although Davis and Hubbard (1972) provide no details with regard to the temporal organisation of these 'interim' behaviours. Behaviour under the VT schedules was much more variable. They note that there were noticeable drifts in topography both between and within sessions. Further, "there was a greater tendency for recorded behaviour patterns to occur away from the feeder tray on the VI (VT) schedules." (Davis and Hubbard, 1972,

p4). The topography of the behaviours emitted under the VT schedule resembled those noted under the FT schedules, most being non-food related, e.g., circling and nosing were relatively frequent. Withdrawal of reinforcement resulted in extinction of behaviours, with extinction being faster after the VT schedule than after the FT schedule (see Skinner, 1948). Duration of IRI did not affect the rate of extinction. The control subjects occasionally behaved in a similar manner to the experimental rats, however, none of their behaviours reached a sufficiently high frequency to warrant their being classified as repeated behaviours. The observed similarity in the behaviours of the control and experimental subjects provides support for Staddon and Simmelhag's (1971) contention that the behaviours which emerge in this kind of experimental situation are controlled by the principles of behavioural variation. The maintenance of some of these behaviours in the experimental subjects, but not the controls, would seem to implicate the principles of reinforcement, as do the results which emerged when food was withdrawn (extinction) (Skinner, 1948). The difference between the VT and the FT schedule supports Fenner's (1980) conclusion that the repeated behaviours are controlled by both momentary probability of food presentation and post-food time. Taken as a whole, Davis and Hubbard's (1972) results are more in line with Skinner's (1948) observations than those made by Staddon and Simmelhag (1971). The finding of topographical drift in the VT schedules - especially intrasession drift - is particularly compelling support for Skinner's (1948) 'law of effect' explanation.

One observation of theirs which may cause some problems for a law of effect account is that there was no relation between duration of IRI and resistance to exinction. Davis and Hubbard (1972) do not provide any information with respect to either the strength (i.e., relative frequency) of the stereotyped sequences which emerged under the different IRIs or speed with which such behaviours arose as a function of IRI duration. Skinner (1948) proposed that such a variable was of crucial importance in this kind of situation.

The major difference between the studies conducted by Skinner (1948) and Davis and Hubbard (1972) on the one hand, and those of Staddon and Simmelhag (1971) and Fenner (1980) on the other, is that the former were concerned with acquisition and short-term maintenance of behavioural sequences, while the latter were concerned with both acquisition and steady-state performances. It may well be the case that the same variables play different roles in these two situations (Zeiler, 1979a).

Although the superstitious conditioning experiment has led to some interesting insights concerning the differences between response-dependent and response-independent reinforcement, it is probably not the most efficacious method of studying the role of response-reinforcer dependency. One of the major problems associated with the superstitious conditioning arrangement is the identification of behaviours to be measured (Staddon and Simmelhag, (1971)

note that the behaviours which Skinner observed - possibly interim behaviours - are particularly salient aspects of the behaviour stream, while terminal behaviours are somewhat more difficult to observe). In order to overcome this problem, experimental analysts of behaviour have adopted different strategies. The basic logic underlying these is as follows. If a dependency between responding and reinforcement is necessary for either response acquisition or maintenance then training a response in the conventional way (i.e., with a response-reinforcer dependency) and following this with exposure to response-independent reinforcement should yield clearer results. The reason for this is that it now becomes possible to investigate the effects of removing a response-reinforcer dependency on a known, measurable, response. Two basic methods have been used. The first, and probably most direct, is to train and maintain a response under one or another response-dependent reinforcement schedule. The organism is then shifted to a response-independent one (e.g. Herrnstein, 1966; Rescorla and Skucy, 1969). Alternatively, other workers have superimposed a response-independent reinforcement schedule onto a response-dependent baseline (e.g., Henton and Iversen, 1978; Rachlin and Baum, 1972). Using the results from these experiments it has become possible to compare the results of applying response-independent reinforcement with other, well researched procedures, e.g., extinction (Rescorla and Skucy, 1969); delay of reinforcement (Schoenfeld et al, 1973); and differential reinforcement of other behaviour (DRO) (Davis and Bitterman, 1971).

2.3. Transition from immediate response- dependent reinforcement to FT schedules

The first study which systematically examined the transition from a response-dependent to a response-independent reinforcement schedule was reported by Herrnstein (1966). He exposed a pigeon to a FI11 sec schedule for 9 sessions before transferring it for 22 sessions of FT11 sec. After a return to baseline phase, the pigeon was exposed to conventional extinction for 16 sessions. Although there was variability in the rate of responding, he found the FT schedule was associated with response decrement. Responding, however, stabilized at above zero level. In contrast, extinction resulted in the elimination of key pecking. Despite using only 1 organism, Herrnstein's (1966) result is fairly typical of transitions from FI to FT schedules when pigeons are used as subjects (Lowe and Harzem, 1977; Shull, 1970, 1971; Zeiler, 1968). For example, Lowe and Harzem (1977) found no response decrement when pigeons were transferred from FI30 and FI60 sec to FT30 sec and FT60 sec respectively. There was considerable decrement when the pigeons were transferred from FI120 sec to FT 120 sec. Rat subjects showed a considerable decrement in responding at all FT values. Such a severe response decrement under an FT schedule with rats as subjects is not an inevitable outcome. Edwards, Peek and Wolfe (1970) trained rats on either a fixed-ratio (FR) 35 or 50 schedule before exposing them to a FT schedule, whose value was the median of the IRI during the FR baseline. They found that

responding was maintained for up to 50 sessions under the FT schedule. The pattern of responding under the FT schedule was similar to that observed under the preceding FR. Zeiler (1968) exposed pigeons to a multiple FT EXT (mult FT EXT) after either mult FI EXT or mult VI EXT. Although he found response decrement when the response-dependent reinforcement schedule was changed to the FT schedule, the result of major interest in this experiment was that the response-independent reinforcement was correlated with a change in response patterning. Transfer from the VI baseline to the FT schedule was associated with the emergence of a positively accelerated cumulative record. Similarly, a change from mult FI EXT to mult VT EXT was correlated with a change from positive acceleration to a more even cumulative record (see also Staddon and Franks, 1975). Differential control of response patterning was not replicated by Alleman and Zeiler (1974). In this experiment, pigeons were transferred from both a DRL and a FR schedule to a FT schedule. Positive acceleration during the FT schedule only emerged after exposure to the FR schedule. Once it had occurred though, it was more likely to recur under the FT schedule irrespective of whether the preceding schedule had been either the FR schedule or a DRL schedule. Alleman and Zeiler (1974) provide no explanation for the lack of control over response patterning by the FT schedule which followed the DRL schedule, although it could be that the control of patterning was determined by the type of discriminative control developed by the reinforcer during the baseline conditions (Franks and Lattal, 1976; Rescorla and Skucy,

1969). Lattal (1972) transferred rats from a mult FI VI schedule to a mult FT VT schedule. He found good maintenance of responding during the response-independent reinforcement conditions, with rate of lever pressing being higher during the FT condition relative to the VT condition. This result appears to contradict those reported by Lowe and Harzem (1977) for their rat subjects. One major difference between these experiments is the presence of differential stimulus-reinforcer contingencies in Lattal's (1972) experiment and their absence in Lowe and Harzem's (1977). There is evidence from the autoshaping literature which indicates that differential stimulus-reinforcer contingencies are sufficient for both response acquisition and maintenance (e.g., Gamzu and Schwartz, 1973). The higher rate of responding during FT relative to VT found by Lattal (1972) could be due to the greater tendency for topographical drift under VT schedules (Davis and Hubbard, 1972).

Apart from Lowe and Harzem's (1977) data for their rat subjects, FT schedules appear to be correlated with a reasonable degree of response maintenance; certainly, total elimination of the response from the behaviour stream is a rare occurrence. Several reasons may be put forward to explain the maintenance of responding under FT schedules. First, in those cases where the transition is from either a FI or FR schedule to a FT schedule, it is likely that the organism's pattern of responding will be of the scalloped or break-run kind. In these cases, the FT reinforcers are

likely to intercept high-rate, short IRT patterns. Such patterns will then be adventitiously contiguous with the reinforcer. This kind of reasoning can account for the positively accelerated patterns of responding after exposure to the FR schedule but not after a DRL schedule which was found by Alleman and Zeiler (1974). Second, the regular presentation of food under FT schedules might induce food-related behaviours. In the pigeon, this kind of consummatory behaviour takes the form of pecking, while in the rat it is likely to take some form of orienting towards the food tray (Lowe and Harzem, 1977; Davis and Hubbard, 1972: Staddon and Simmelhag, 1971). Thus, given the pigeons in these experiments were trained to keypeck, it is likely that responding will be maintained, especially if the IRIs are not too long (Lowe and Harzem, 1977; Staddon and Franks, 1975). Decrement in the measured response could be due to either a drift in the peck response away from the key or key pecking which is insufficiently forceful to record a response (Staddon and Simmelhag, 1971).

Although FT schedules may be of interest in their own right, the variables noted above seem to preclude their use as the method of choice for analysing the role of response-reinforcer dependency (Rescorla and Skucy, 1969). It would therefore seem appropriate to examine VT schedules at this stage.

2.4. Transition from immediate response-dependent reinforcement to VT schedules.

The first studies to examine the transition from response-dependent reinforcement to a VT schedule were those reported by Rescorla and Skucy (1969) and Zeiler (1968). Rescorla and Skucy (1969) reported 4 experiments in which rats were exposed to VI schedules before being transferred to VT schedules, the parameters of which were the same as the programmed rate of reinforcement under the prior VI. The behaviour under the VT schedule was compared with that emitted under extinction and a DRO presented under a VI schedule in a between-groups design. They found that response decrement was slower under the VT and DRO schedules relative to the extinction procedure. The VT and DRO did not differ. Lever pressing usually stabilized at above zero level even after 20 sessions of VT reinforcement. In the last 3 experiments in the series, Rescorla and Skucy (1969) attempted to isolate the variables responsible for the maintained responding during the VT condition. They rejected a 'superstitious conditioning' view because allowing the VT schedule to enter the behaviour stream when responding was at different rates had no differential effect (the assumption here was that if such a view had explanatory power, then one would be more likely to obtain maintained responding if one allowed the VT schedule to contact higher rather than lower rates). Their manipulation of response rates took a rather unconventional form in that the VT schedule was introduced after varying numbers of extinction sessions. Given that the same VT schedule was correlated

with response decrement in experiment 1, in which no extinction sessions interceded between the VI and VT conditions, it is not surprising that no differences between the groups emerged. In place of adventitious contiguities as the mechanism of response decrement/maintenance, they proposed that food developed discriminative control properties which led to an increase in the likelihood of lever pressing in the VT condition relative to the no-food conditions. Apart from this difference, response-independent reinforcement and extinction were regarded as being functionally similar. There is evidence which confirms the view expressed by Rescorla and Skucy (1969) that food can acquire discriminative control over responding. Franks and Lattal (1976) exposed rats to both DRL and variable-ratio (VR) schedules. Responding was then extinguished. Finally, the rats were exposed to a FT2 min schedule. They found that FT after the VR-EXT condition was correlated with a much higher rate of responding than FT after the DRL-EXT condition. In a direct test of Rescorla and Skucy's (1969) contention that response-independent reinforcement is a variant of extinction, Boakes and Halliday (1975) attempted to demonstrate both spontaneous recovery and disinhibition under both VT and extinction conditions. The animals (rats) were first exposed to VI1 min schedule before being transferred to either a VT1 min schedule or extinction. They were not able to demonstrate disinhibition. Spontaneous recovery was observed in those rats undergoing extinction, but it was absent in the VT group. In a later experiment, some evidence of spontaneous

recovery was reported for the VT group; however, it only occurred after substantial response decrements had taken place and sessions were relatively long. No such constraints were evident for its demonstration under extinction, where it occurred in the early sessions irrespective of the session duration. Boakes and Halliday (1975) also question the central role given to the response-eliciting properties of reinforcement in the maintenance of responding under VT conditions. They found that response decrement was slower after VT2 min relative to VT30 sec. (experiments 2 and 3 respectively). If Rescorla and Skucy's (1969) view is correct then the reverse should be true. Boakes and Halliday (1975) preferred a response-competition view. Boakes (1973) has also found that response decrement is slower after VT relative to extinction. Other data also serve to disconfirm Rescorla and Skucy's (1969) position that response-independent reinforcement is a variant of extinction (Lattal and Maxey, 1971).

The transition from a VI schedule to a VT schedule has also been examined by Lattal (1972, 1974), Lattal and Maxey (1971), Sizemore and Lattal (1977), Davis and Bitterman (1971), and Williams (1976). There have been transitions from response-dependent schedules other than a VI to VT. Zeiler (1968) has examined the transition from FI to VT schedules; while Catania and Keller (1981) have examined the transition from a VR schedule to a VT schedule. Davis, Iriye and Hubbard (1973) have analysed the transition from a DRL schedule to a VT schedule. Finally, Lachter and his

colleagues have reported studies in which the transitions were from schedules based upon the t-tau systems (Schoenfeld and Cole, 1972) to VT schedules. The general result emerging from all of these studies is that, irrespective of the baseline schedule, the VT schedule is associated with a decrement in the measured response - sometimes to zero level (e.g., Boakes, 1973; Lachter, 1971; Lachter, Cole and Schoenfeld, 1971).

The experiments differ from each other in several important respects. Continuity only appears when the experiments are the product from one laboratory.

Davis and Bitterman (1971) exposed rats to a VI30 sec schedule. The rats were then formed into pairs, one being exposed to a DRO 10sec schedule, while the other in the pair was yoked to it (yoked VT). Response decrement was much more severe for the DRO rat. This was more obvious in subsequent phase where the DRO-yoked condition (DRO 30sec) was alternated on a session-to-session basis with the VI30 sec schedule (compare with Rescorla and Skucy, 1969). Lowry and Lachter (1977) have found results which are consonant with those of Davis and Bitterman (1971). I shall return to a discussion of the similarities and differences between response-independent reinforcement schedules and DRO schedules in section 2.5.

Lattal and his colleagues have examined the transition from VI to a VT schedule within a multiple schedule format. By

using this type of condition, they have been able to compare rates controlled by a VT schedule with those controlled by both a FT and an EXT component schedule. Lattal and Maxey (1971) examined the transitions from a mult VI VI schedule to a mult VI VT schedule; from mult VI VI to mult VI EXT; from mult VI EXT to mult VI VT (1 session probes); and from mult EXT EXT to mult VT VT. The results were as follows. Response decrement occurred during the VT component relative to the prior VI schedule. Nevertheless, responding did not cease during the VT component over 35 sessions. Response rate decreased further when both components were VT schedules; when one was replaced by a VI schedule positive induction was found (i.e., an increase in rate in both the changed VI component and the unchanged VT component). There was slight evidence of a negative induction effect when the transition was from mult VI VI to mult VI VT (see also Boakes, 1973). The effect of the VT probe session on the EXT baseline was to increase rate of responding (Rescorla and Skucy, 1969; Franks and Lattal, 1976). Lattal and Maxey (1971) proposed that the maintained responding during the VT conditions was due to a combination of adventitious response-reinforcer contiguities, the VI conditioning history and the interaction between the component schedules. Lattal (1972) exposed rats to a mult FI VI schedule before transferring them to a mult FT VT schedule. He found that responding was maintained in each component. The different time schedules also appeared to be correlated with different response patterns (see also Zeiler, 1968). The differential patterning, however, could be a function of the baseline

reinforcement schedules (Alleman and Zeiler, 1974). The difference in the degree of response decrement between the studies of Lattal (1972) and Lattal and Maxey (1971) on the one hand and that of Rescorla and Skucy (1969) on the other could be due to either the difference in the number of baseline response-dependent reinforcement sessions or the presence of differential stimulus-reinforcer contingencies in the studies from Lattal's laboratory. It is certainly true that Lattal's studies usually have many more baseline sessions than Rescorla and Skucy (1969) used - Lattal (1972), for example, used between 37 to 40 sessions, while Rescorla and Skucy (1969) only had 5. There is other data where a relatively large number of sessions are given in baseline, yet response elimination occurs during the VT condition (Lachter, 1971). It therefore seems more likely that the differential degree of response decrement was due to the presence of differential stimulus-reinforcer contingencies. These would interact with adventitious response-reinforcer contiguities (see Lattal and Maxey, 1971). There is some evidence to suggest, however, that differential stimulus-reinforcer contingencies are not as powerful in generating and maintaining a response when the subjects are rats and the response in question is the lever press, as would be the case where the subjects are pigeons and the response is the key peck (e.g., Bradshaw, Szabadi and Bevan, 1978; McSweeney, 1977). Nevertheless, there is no doubt that rats can be autoshaped to lever press when the signalling stimulus is on the manipulandum (Boakes and Linaza, 1975).

The use of multiple schedules in which the different components signal different rates of reinforcement cannot be responsible for all cases of response maintenance during VT or related conditions, however, because there are cases in the literature where they have been used but considerable response decrement has occurred. For example, Lachter et al (1971) and Lachter (1971) have reported such an effect. These experiments were designed to assess the effects of different rates of reinforcement upon responding during response-independent conditions. In one experiment the rate of reinforcement was varied during baseline, while in the second, reinforcement rate was varied during the response-independent condition. Specifically, Lachter et al (1971) exposed pigeons to a six component multiple schedule in which each component was associated with a RI60 sec schedule. This was followed by exposure to a mult RT5 RT15 RT30 RT60 RT120 RT240 sec schedule. This was kept in force for 30 sessions. They found response decrement in each component. It was slowest, however, in the 5 sec component. Indeed, response rate was above baseline for up to 24 sessions for both birds during the RT 5 and 15 sec components; it was also higher than baseline for the stimuli associated with the RT30 and 60 sec schedules for one bird. In both cases, however, there was considerable response decrement by the thirtieth session. In a subsequent experiment, Lachter (1971) sought to examine the effects of response-independent reinforcement upon different rates of responding. Pigeons were exposed to a mult random ratio

(RR) 10 RI30 RI60 RI120 RI240 sec before being transferred to a nondifferential multiple schedule in which the components were one of the following values - RT30, RT60, RT120, FT30, FT60 or FT120 sec. Lachter's (1971) manipulation of response rate during baseline was successful, the highest rate being maintained by the RR schedule. There was an inverse relation between RI value and response rate. Lachter (1971) found that the different time schedules (i.e., RT vs FT) did not differentially affect response maintenance. With regard to resistance to response-independent reinforcement, the general picture was as follows. Maintenance of responding was strongest after both the RI30 and RI60 sec schedules. There was a trend for the RI120sec schedule to produce stronger resistance than that produced by the RI240sec schedule. The weakest effect was observed after exposure to the RR10 schedule. Therefore, rate of responding during baseline was a reasonable predictor of subsequent response maintenance during the RT schedules when the RI schedules are considered. Such a result finds support from Nevin (1979b) when the indices of response strength were resistance to extinction and a free food manipulation. The result emerging from the RR10 schedule, however, is at odds with this conclusion. Lachter (1971) notes that there was a marked discrepancy between reinforcement rates during the RR10 schedule and all of the response-independent schedules; thus the transition in this case was similar to being transferred to an extinction condition. Both Lachter (1971) and Lachter et al (1971) adopt a response competition view based upon a contiguity

mechanism to explain their results.

There are a few examples of transitions from immediate reinforcement schedules other than interval schedules to VT schedules in the literature. Davis et al (1973) exposed rats to a VT schedule after training on a DRL20 sec schedule. Unusually, VT reinforcement rates were exactly matched to obtained reinforcement rates during the preceding DRL sessions. They found a rapid decrement in responding during the VT schedule. Their results indicated that there was an inverse relationship between efficiency of responding during DRL training and subsequent resistance to response-independent reinforcement. This result therefore provides some confirmation for the position proposed by Lachter (1971), since it is likely that inefficient responding during a DRL schedule is positively correlated with response rate (the index of efficiency was responses per reinforcer during the DRL sessions). Catania and Keller (1981) have reported a study in which pigeons were first exposed to a VR20 schedule prior to being transferred to a VT10 sec schedule. They report 4 such transitions. They found considerable response decrement, sometimes to zero level, after 40 sessions. Of interest was their observation that resistance to response-independent reinforcement became weaker after each succeeding transition. They point out that this trend indicates some sort of learning set, and provides evidence for a molar, correlation view (Baum, 1973, see section 2.6.2).

The major effect of a transition from an immediate reinforcement schedule to a response-independent reinforcement schedule is usually response decrement. There are cases in the literature, however, where there is either no decrement in response rate or where there is a transient increase in responding. Further, at times there is a considerable and rapid rate of response decrement, while in other studies, response decrement is relatively slow and responding stabilizes at levels well above zero. The variables of which these changes are a function are unknown. Nevertheless, some general points can be made.

1. Reinforcement appears to develop discriminative control over responding. This factor probably plays some role in the maintained responding sometimes observed during exposure to time schedules (Rescorla and Skucy, 1969). There is evidence to suggest, however, that this variable cannot be responsible for all cases of maintained responding (Boakes and Halliday, 1975).

2. There is some evidence to suggest that there is a positive relation between rate of responding during the baseline schedule and subsequent resistance to response-independent reinforcement (Lachter, 1971). This result may be limited to those cases where the discrepancy between reinforcement rate during the response-dependent phase and the response-independent phase is not too great (Lachter, 1971). Fixed ratio schedules appear to produce greater resistance to response-independent reinforcement than to interval schedules - at least when comparisons are made across studies (Alleman and Zeiler, 1974; Edwards et al,

1970; Rescorla and Skucy, 1969). There have not been any studies in which the response persistence produced by a FR schedule has been compared with that of a yoked interval schedule (i.e., where reinforcement rates are controlled).

3. Responding during time schedules tends to be more persistent if differential stimulus-reinforcer contingencies are present (Lattal, 1972; Lattal and Maxey, 1971; Zeiler, 1968; but see Lachter, 1971; Lachter et al, 1971).

4. Response maintenance tends to be stronger under time schedules when the reinforcer deliveries are periodic rather than aperiodic (Lattal, 1972; Lowe and Harzem, 1977; Zeiler, 1968; but see Lachter, 1971). This is especially likely to be the case when pigeons are used as subjects and the conditioned response is the keypeck.

5. Time schedules sometimes control response patterning (Zeiler, 1968). There are cases, however, where the baseline schedule appears to be a much more important determinant of response patterning (Alleman and Zeiler, 1974; Edwards et al, 1970).

6. Time schedules consistently maintain responding for longer periods relative to conventional extinction, irrespective of the baseline schdule or the presence/absence of differential stimulus-reinforcer contingencies (Boakes, 1973; Edwards et al, 1970; Lattal and Maxey, 1971; Rescorla and Skucy, 1969). The view that response-independent reinforcement is a variant of extinction is probably untenable (Boakes and Halliday, 1975).

Although these general statements can be made, it should

also be noted that, apart from point 6, there are exceptions to each conclusion. One reason for the tentativeness of these points is that the experiments described vary from each other in important details. Basic variables, such as amount of pretraining, have yet to be assessed. For example, some experimenters have given as few as 5 or 6 baseline sessions (Boakes, 1973; Rescorla and Skucy, 1969) while others have given up to 40 (Lattal, 1972; Lowe and Harzem, 1977) or even more (Lachter et al, 1971). Where only 5 or 6 sessions are given there may be reason to believe that steady-state had not yet been achieved. Another variable which has not been systematically examined, but may be of importance, is rate of reinforcement. Some experimenters have attempted to match at least the rate, if not temporal distribution, of reinforcement across the response-dependent and independent phases (Lachter, 1971; Lachter et al, 1971; Lattal, 1972; Lattal and Maxey, 1971; Rescorla and Skucy, 1969; Sizemore and Lattal, 1977). Some have attempted to match both rate and temporal distribution of reinforcement across phases (Davis et al, 1973); finally, others have simply chosen some arbitrary value (Alleman and Zeiler, 1974). Given that there is evidence that rate of reinforcement and its temporal distribution can be an important determinant of responding under response-independent reinforcement conditions, it is regrettable that no systematic investigation of these variables has been carried out. Finally, most of the experiments reported here provide data in the form of means from a number of sessions (sometimes as many as 6). Given the variability inherent in

data gathered when reinforcers are response-independent, at least session-to-session data or even within session data might be required. It is ironic that some writers who make appeal to molecular contiguity mechanisms present their own data in the form of means from blocks of 6 sessions (Lachter, 1971). The prevailing level of analysis is probably too gross.

2.5. Superimposing response-independent reinforcement onto response-dependent baselines.

Superimposing response-independent reinforcement onto a response-dependent reinforcement baseline has been a convenient strategy, because the effects of free reinforcement can be examined over long periods of time.

Typically, the effects of such a manipulation has been compared with that of super-imposing a DRO schedule onto the same baseline. There are two reasons for this comparison. First, DRO schedules reinforce not-responding, or the emission of a response incompatible with the previously reinforced operant. To the exent that FT or VT schedules have their effect on behaviour according to a similar mechanism, so the results of these two manipulations should be similar. Second, one study in particular, that reported by Rachlin and Baum (1972), has had a seminal influence in this field. That experiment made the contrast between a DRO and VT schedule when each was superimposed upon a VI baseline. A number of subsequent studies have been designed to examine their findings. Before turning to that

experiment, however, a note on schedule nomenclature is required at this point. I shall then review data from experiments which did not take Rachlin and Baum's (1972) results as their starting point. This section will culminate in a discussion of that paper and related experiments.

There is some inconsistency in the way in which conventional schedule terms are used in this context. Some writers (Henton and Iversen, 1978; Rachlin and Baum, 1972) have used the term concurrent schedule to apply to those cases where one schedule is superimposed upon another. Others have used the term conjoint schedule (Zeiler, 1976; Lattal and Bryan, 1976) to describe the same arrangement. In this section I reserve the term concurrent schedule to refer to those cases where either 2 separate manipulanda are used and independent schedules are programmed on each or where the same manipulandum is used, but two different responses are reinforced. Emission of either response precludes the possibility of emitting the other. Thus, where a DRO schedule is superimposed onto a response-dependent baseline and that schedule is used to reinforce the emission of some response (e.g., keypeck) then the term concurrent schedule is used, because 2 different, incompatible, responses are capable of producing reinforcement. In all other cases the term conjoint schedule is used. Thus when a VT schedule is superimposed upon a VI baseline such a schedule is called a conjoint schedule, because the organism could be emitting the response when a VT reinforcer became available or

emitting some other behaviour. I have therefore renamed some of the schedules used by some authors in terms of the distinctions made above.

In one of the first experiments to be reported in this field, Edwards et al (1970) trained rats on a FR baseline schedule. They then varied the rate of FT reinforcement superimposed on to this baseline. In a second experiment, they held the FT value constant and varied the FR parameter. They found that adding the FT component to the FR baseline resulted in response decrement, but only when the frequency of FT reinforcement was increased over the baseline FR reinforcement rate (either twice or 4 times baseline rate). When FT reinforcement rate was equal to that obtaining during baseline, little or no decrement in responding was found (note that in this case the rats would be receiving twice as much reinforcement as they had during the baseline condition). Reducing the FR parameter, while holding the FT schedule constant, resulted in a reduction in response rate, which was recovered when the FR parameter was increased. Therefore, reducing the average IRI resulted in a reduced rate of responding.

Lattal (1973) exposed rats to both a mult VIVT and a mixed (mix) VIVT schedule. He found that the rate of responding during VT component of the mixed schedule was equal to that obtaining during the VI component. Rate of responding during the VI component was higher than that during the VT component in the multiple schedule condition. In a

subsequent manipulation, component duration was increased (from 5 min) in the mixed schedule. This resulted in rate of responding during the VI schedule being higher than that observed during the VT schedule. A similar result has been reported by Green and Rachlin (1975) where a VT schedule was superimposed upon a VI schedule within a multiple schedule format. When an additional VI schedule was superimposed upon the original VI schedule, no such decrement in response rate occurred when the duration of the components was increased. Lattal (1974) varied the percentage of response-independent reinforcement on a normal VI schedule. Specifically, 0%, 33%, 66% or 100% of the reinforcers could be response-independent. He found that there was a direct relation between percentage of response-dependent reinforcers and response rate (see also Schoenfeld et al, 1973, experiment 3).

Wilkie (1972) exposed rats to a concurrent (conc) VI60 VI60 sec schedule with a 2 sec change-over delay (this was a Findley procedure rather than a 2-lever procedure. They were then exposed to a conc VT60 VT60 sec schedule. He found that 1 rat responded at much the same rate during the VT schedule as it did during the VI schedule, until 3 sessions of DRO training were imposed during the VT component. (Zeiler, 1976). Wilkie (1972) found no differences in terms of relative time allocation for the VI or VT conditions.

Rachlin and Baum (1972) exposed pigeons to a conjoint (conj)

VI3 min VI3 min schedule before transferring them to either a conc VI3 min DRO2 sec (presented according to a VI3' schedule) or a conj VI3 min VT3 min schedule. Parameters such as signalling the non-VI reinforcer, amount and rate of reinforcement were also varied. They found that rate of keypecking varied inversely with the amount or rate of extra reinforcement, irrespective of the source, i.e., response decrement associated with the DRO and the VT schedules was the same. In addition, the rate of VT and DRO reinforcement did not differ. They took these results as providing evidence against a contiguity view because the opportunity for chance response-reinforcer contiguities was higher during the VT condition than it was during the DRO component (in which such contiguities can never occur). Rachlin and Baum's (1972) results have been examined in a number of subsequent experiments.

Zeiler (1976) trained pigeons on a FI3 min schedule. Then either a FT or DRO schedule was superimposed onto this baseline. The time parameters (t) for the FT and DRO schedules were one of the following values - 10, 20, 30, 60 and 100 secs. He found that both the FT and the DRO schedules reduced FI response rate; there was an inverse relation between t value and response rate. Two of the birds were exposed to the FT condition before being given the DRO condition. In these cases, rate of responding increased over baseline, this being especially noticeable at the lowest t values. Once they had been exposed to the DRO schedule, however, rate of responding was related in an

orderly manner to the parameter value under every FT schedule. Zeiler (1976) also found that as the DRO value increased, so the relative rate of FI reinforcement increased (i.e., there was less likelihood of the DRO schedule intercepting the behaviour of the subject). This did not affect the amount of response decrement, i.e., response decrement was similar for the FT and DRO schedules despite the wide discrepancies in relative reinforcement rates. This result is in disagreement with the findings of Rachlin and Baum (1972). Clearly, the source of alternative reinforcement 'does matter'. Zeiler has been able to confirm these results in two later experiments. In the first of these, Zeiler (1977b) exposed pigeons to either a VR100 or VI100 sec schedule. He then superimposed various FT and DRO schedules onto these baselines. The DRO and FT schedules were presented as unsignalled second-order schedules where the total t values were 3, 10, 30 and 90 sec. Once more he was able to demonstrate an inverse relation between t value and response rate (see also Edwards et al, 1970). He concluded that "Even at low time requirements where the schedules operate most similarly, the DRO is likely to establish the lower rate. With still longer times, DRO consistently generates less responding. Then with the longest times, FT may establish lower rates than DRO because the DRO requirements are rarely, if ever, met." (Zeiler, 1977b, p31). These results are once again in opposition to those found by Rachlin and Baum (1972). In the final experiment in the series, Zeiler (1979b) superimposed DRO and FT schedules with t values of 10, 20,

40, 80 and 120 sec onto both FR 180 and FR300 schedules. He found that the DRO schedules with values of 10, 20 and 40 sec eliminated responding on the FR180 schedule. Responding on the FR300 schedule was eliminated at all DRO values. For the FT schedule, t values of 80 and 120 sec were often associated with response rate increases over the FR180 baseline. For the FR300 schedule, both the FT10 and 20 sec schedules eliminated responding. Key pecking was well maintained at all other FT values. Although, the DRO and FT schedules had similar effects at low t values, they had markedly different ones at the longer values. Zeiler (1979b) comments "To the extent that FT does involve alernative reinforced responses, the alternatives probably are less clearly defined and less often the pure converses of each other than happens with DRO." (Zeiler, 1979b, p331). Taken as a whole these results provide strong support for an adventitious reinforcement view. Clearly, all 3 experiments provide contradictory evidence with regard to the results found by Rachlin and Baum (1972).

In a series of studies, Lattal and his colleagues have found results which support those of Zeiler (1976, 1977b, 1979b). Lattal and Bryan (1976) have reported two experiments in which pigeons were transferred to either conj FI VT or conj FI FT schedules after being trained under a FI schedule. In another experiment reported in the same paper, pigeons were initially exposed to a mult FI FI schedule prior to being given a multiple schedule in which the components were either conc FI VI or conj FI VT schedules. In all of the

experiments, they found that response patterning was markedly affected when the additional schedules came into force. For example, when the changed schedule was a conj FI VT schedule (experiment 1), the quarter-life scores changed from 0.42 and 0.45 (for 2 birds) during the baseline FI schedule to 0.24 and 0.28 during the conjoint schedule. This indicates that there was a loss of positive acceleration; responding was more evenly spread throughout the IRI. A similar result obtained when the added component was either the VI or VT schedule (experiment 2). When the added schedule was an FT one (experiment 3) which was 1/3 the value of the prevailing FI, positive acceleration took place within the FT values. In terms of rate of responding, there were a number of cases where increases were noted during the changed condition relative to the baseline schedule. This was most obvious in experiment 1 when the transition was from FI5 min to conj FI5minVT2.5min. When the rate of VT reinforcement was increased, response rate decreased (see also Edwards et al, 1970). There is the possibility that when the VT parameter is relatively short compared with the FI parameter, some of the shorter interval VT reinforcers would intercept the post-reinforcement pause (PRP). In this experiment, the VT values associated with response decrement were 30 sec and 1.5 min. Response rate increases, however, were not limited to experiment 1. Two of three birds increased their rate of responding during experiment 3, when the transition was from FI1 min to conj FI1 min FT0.33 min. There was also one case of increased rate of responding in experiment 2, where the multiple

schedule was used. The general conclusion that can be drawn from this series of experiments is that there is an inverse relation between rate of response-independent reinforcement and response rate.

In a later experiment, Lattal and Boyer (1980) contrasted the effects of superimposing either a DRO or VT schedule onto a FI 150 sec baseline. The DRO was presented on a VI150 sec schedule and had t values of 0.2, 0.5, 1, 2, 5, 7.5, 10, 20 and 30 sec. The VT was always a VT150 sec schedule. The birds in this experiment were not exposed to all of the DRO values. Lattal and Boyer (1980) measured both response rate and pause duration. They found that introducing the VT schedule after the FI was associated with both a reduction in pausing and an increase in response rate. Replacing the DRO schedules with the VT schedule was correlated with an increase in response rate. Response patterning during the conj FI VT schedule resembled that observed during the appropriate conditions in the report by Lattal and Bryan (1976). These studies all provide strong support for the results which were found by Zeiler (1976; 1977; 1979b). Clearly, frequency of response-independent reinforcement is an important determinant of response rate in this situation.

Using a more molecular approach, Henton and Iversen (1978) have re-examined the procedure used by Rachlin and Baum (1972). They report an experiment in which 2 rats were initially exposed to a conj VI1 VI1 min schedule. The rats

were then transferred to a conj VI1 VT1 min schedule. Over subsequent phases this schedule was altered. In the next condition, the VT reinforcer would only be delivered if a response had occurred within one second of its being due. This condition was then reversed such that the VT schedule became a DRO 1sec schedule, which was presented according to a VT1 min (i.e., a VT reinforcer would be delivered if at least 1 second had elapsed without a response before that VT reinforcer was due). During the last two phases, the VI schedule remained in effect. The conj VIVT schedule was then reintroduced. Finally, the rats were exposed to a simple VT1 min schedule and a conventional extinction condition. Henton and Iversen (1978) analysed their results in terms of response probability, the percent of food pellets which were contiguous with a response (contiguity being defined as less than 1 second), and the sequential structure of behaviour (during the conj VIVT and VT conditions). In terms of response probability, introduction of the conj VIVT schedule, was associated with a reduction in the probability of lever pressing. Constraining the VT schedule such that a pellet of food could only be delivered if a lever press had occurred within 1 second of the reinforcer being due (technically, a brief variable delay of reinforcement schedule) resulted in an increase in lever press probability to levels comparable with those observed during the response-dependent baseline (see also Lattal and Ziegler, 1982; Sizemore and Lattal, 1978). Introduction of the DRO reduced lever press probability markedly, while reintroducing the conj VIVT condition resulted in its

recovery. Imposing the simple VT schedule was correlated with a reduction in lever press probability, but to above zero level. Lever press probability was inversely related to the percentage of food pellets contiguous with 'other' behaviour. The sequential analysis revealed rapid drifts in topography (Davis and Hubbard, 1972). When a particular behaviour was contiguous with a reinforcer, however, its probability of occurrence increased. As Henton and Iversen (1978) note "These examples clearly show that the particular response preceding pellet delivery was often emitted again after pellet retrieval. Typically, the effect was transient, but became more persistent, perhaps dominating one or more successive sequences, if that response was followed relatively quickly by a second pellet delivery." (Henton and Iversen, 1978, p212). It is clear from this report that 'other' behaviour formed part of the pattern of the operant, even though the schedule did not demand it (Zeiler, 1972). These data indicate that the source of additional reinforcement does matter. It is also the clearest data available which provide direct support for a contiguity position. In summarizing the experiments from this section, the following conclusions may be reached.

1. Response rate is inversely related to rate of response-independent reinforcement. This is the case irrespective of the baseline schedule, or kind of time schedule which is superimposed upon the response-dependent reinforcement schedule (Edwards et al, 1970: Lattal and Boyer, 1980; Lattal and Bryan, 1976; Zeiler, 1976, 1977b, 1979b). There are no published exceptions to this rule.

2. Superimposing a DRO schedule onto a response-dependent baseline generally results in greater response decrement relative to superimposing a time schedule. The only exceptions to this rule are either where the DRO value is very large, such that the organism hardly ever contacts it (Zeiler, 1977b) or where the t values of the DRO and time schedules are very short relative to the baseline response-dependent reinforcement schedules (Henton and Iversen, 1978; Lattal and Boyer, 1980; Zeiler, 1977b, 1979b).

3. The effects of superimposing a time schedule onto a response-dependent baseline are variable. Sometimes response decrement occurs while at other times no response decrement is observed. In some cases an increase in response rate is observed (Boakes, Halliday and Poli, 1975; Edwards et al, 1970; Lattal and Boyer, 1980; Lattal and Bryan, 1976; Zeiler, 1979b).

4. Where free reinforcement is superimposed onto a response-dependent baseline in the context of both a multiple and mixed schedule, component duration is inversely related to response rate in the component in which the time schedule is added (Boakes et al, 1975; Green and Rachlin, 1975; Lattal, 1973).

5. Adding either a FT or VT schedule onto either a FI or FR baseline changes the pattern of responding relative to that induced by the baseline schedule on its own (Lattal and Boyer, 1980; Lattal and Bryan, 1976; Zeiler, 1979b).

Although the results from this section seem to be somewhat clearer than those reported in the previous sections, a

great deal of variability still exists. For example, it is not possible to delineate the boundary conditions for response maintenance. Where variability in data exists, theories of the processes responsible for such variability usually are proposed. This area is no exception. Two theories have gained adherents in this context. Both of these will now be reviewed.

2.6. Theories of the effects of response-independent reinforcement

Two major positions have been advanced to explain the effects of response-independent reinforcement on either a response previously maintained or presently maintained by a response-dependent reinforcement schedule. These are the contiguity view proposed by Schoenfeld and his colleagues (Schoenfeld et al, 1973) and the correlation view advanced by Baum (1973), Rachlin (1976) and Killeen (1978, 1981).

2.6.1. Schoenfeld's Contiguity View

Schoenfeld and Farmer (1970) and Schoenfeld et al (1973) have presented critical reviews of the notion of response-reinforcer dependency. In so doing, they have also presented a theory of reinforcement schedules which seeks to bridge the gap between response-dependent and response-independent schedules. As pointed out in section 1.3.1.1., the main difference between these schedules is that in the former, the temporal distribution of R determines the temporal distribution of reinforcement. This relationship is lacking in the latter. The two are similar, however, in

that the temporal distribution of the reinforcer determines the temporal distribution of R, or in the case of response-independent schedules, both R and $\not R$. This is not always obvious in free reinforcement schedules because usually only one R (the designated operant) is monitored. Schoenfeld et al (1973), however, would argue that the superstitious conditioning literature demonstrates that even where no programmed response-reinforcer dependencies exist, the temporal distribution of the reinforcer still determines the temporal distribution of the various responses that make up the behaviour stream.

Schoenfeld and Farmer (1970) and Schoenfeld et al (1973) have attempted to isolate the variables which control the rate of responding during response-independent reinforcement by appealing to the relevance of their notion of the behaviour stream (see section 1.3.2.1.1.). When applied to schedules of reinforcement, it can be seen that these can distributed along a continuum. The variable underlying this continuum is the relationship between both R and $\not R$ with reinforcement, (see also Zeiler, 1979a). At one end of the continuum are the immediate reinforcement schedules, in which only R can be contiguous with the reinforcer. At the other extreme are the response-independent reinforcement schedules, in which both R and $\not R$ are free to be contacted by the reinforcer. The schedules can be further separated on the basis of whether both R and $\not R$ must occur if reinforcement is to be dispensed (e.g., DRL schedules), or whether only R-occurrences or $\not R$-occurrences are required for

reinforcement (conventional VI, FI, FR and VR schedules as opposed to DRO schedules). In between the immediate reinforcement schedules and the response-independent reinforcement schedules are the delay of reinforcement schedules. In terms of similarity to the time schedules, unsignalled variable delay schedules are closer than are either unsignalled fixed delay schedules or signalled delay schedules. Use of this scheme allows Schoenfeld et al (1973) to explain some of the results which have emerged from studies on response-independent reinforcement. The response decrement observed during free reinforcement schedules after training on immediate reinforcement schedules is accounted for by proposing that on the FT or VT schedules, the reinforcer begins to contact $\not{R}$. This behaviour is strengthened at the expense of R, i.e., it becomes relatively more frequent in the behaviour stream. Response decrement, however, does not always proceed at an even rate. There are occasions where the reduction of R-rate is much quicker than in others (e.g., Boakes, 1973; Lattal, 1972). Schoenfeld and Farmer (1970) and Schoenfeld et al (1973) maintain that the rate of response decrement is a function of the following variables. The frequency of R during the baseline; and the frequency of reinforcement during the response-dependent and response-independent phases. Schoenfeld and Farmer (1970) note that "If the rate of R is high, and intruding $\not{R}$s are necessarily shorter, there is a greater probability of the reinforcer intercepting an R; consequently, removing the contingency may not have much of an effect in lowering the rate of

R . . . and it may even increase the rate of R." (Schoenfeld and Farmer, 1970, p236). Along the same lines, Schoenfeld et al (1973) have noted that " . . . our ability to increase, maintain or reduce R rate awaits only the discovery of the proper values of schedule parameters to obtain the desired result." (Schoenfeld et al, 1973, p158). According to this view, response decrement during free reinforcement schedules is not a necessary outcome.

It is difficult to evaluate this theory because the molecular detail which is required is rarely provided (but see Henton and Iversen, 1978). Nevertheless, it is possible to compare studies on the basis of the baseline rates of responding. For example, it is noticeable that the rate of responding during the VI schedule used by Rescorla and Skucy (1969) was about 10 responses per minute, while that found by Edwards et al (1970) was in the region of about 120 response per minute. Examination of other data reveals that Lattal (1972) found mean rate of responding during the FI1min schedule ranged from 61.8 to 93.1 response per minute while the range for the VI1' schedule was 55.8 to 103.4 response per minute. Responding was maintained at a higher rate in those studies which had higher baseline rates. Lattal's (1972) results are of particular interest in this context. It was noted in section 2.3 that the rate of responding during the FT condition was higher than that maintained by the VT schedule. This was the case whether absolute rates or normalized rates were the index. Lattal (1972) published overall rate of responding and what he termed 'terminal' rate of responding (i.e., rate prevailing

during the final 15 sec of the FT schedule). Terminal rate exceeded absolute rate - sometimes by as much as 50 response per minute. Free reinforcers were likely, then, to intercept much shorter IRTs on the FT schedule than they were on the VT schedule. According to the theory advanced by Schoenfeld et al (1973), responding should have been maintained at a higher rate during the FT relative to the VT schedule, which, indeed, was the case. Although, these results may be suggestive, it has to be borne in mind that all of the studies mentioned either used different baseline schedules, or the same schedule with differnt parameters. The only set of studies which might provide direct evidence concerning the theory advanced by Schoenfeld et al (1973), are those reported by Lachter (1971) and Lachter et al (1971). These, however, are flawed because of the presence of differential stimulus-reinforcer contingencies during either the baseline or free reinforcement phases. Schoenfeld et al's (1973) theory also provides a workable explanation of the results which have emerged from those studies in which response-independent reinforcement has been superimposed upon a response-dependent baseline. It will be recalled that there were cases in that literature in which the free reinforcement was associated with an increase in the rate of responding over baseline (Lattal and Boyer, 1980; Lattal and Bryan, 1976; Zeiler, 1979b). In these cases, the response-independent reinforcers were probably intercepting high R-rates. It is noticeable that the increases in rate of responding took place on either FR (Zeiler, 1979b) or FI (Lattal and Boyer, 1980; Lattal and

Bryan, 1976) baseline; i.e., schedules which are associated with high terminal rates. Further, response decrement took place on these schedules when the t values associated with the response-independent schedules were low. It is likely, that in such cases, the free reinforcers were probably delivered during the PRP, i.e., during a period in which $\not R$ was the emitted 'response'. As Schoenfeld et al (1973) note, the obtaining of response decrement, response increment or neither is parameter dependent.

One of the most interesting predictions that can be derived from the postion by Schoenfeld et al (1973) is that response-independent reinforcement bears a strong similarity to a variable delay of reinforcement schedule. In both, both R and $\not R$ are permitted to occur and both R and $\not R$ can be contiguous with the reinforcer. The sole difference between the two is that in the delay schedule there must be at least one R-occurence between reinforcers. This constraint is relaxed in the response-independent reinforcement preparation. Schoenfeld et al (1973) propose that responding will be maintained indefinitely when the transition made is from delayed reinforcement to response-independent reinforcement as long as both the rate and temporal distribution of reinforcers are matched across conditions. These two predictions will now be examined.

2.6.1.1. Delayed reinforcement and response-independent reinforcement: A comparative examination.

Delayed reinforcement can be arranged in various ways. It

can be either signalled by an exteroceptive stimulus (technically, a chain schedule) or unsignalled (a tandem schedule). Such schedules can have either resetting delays (either chain or tandem schedules with the final component being a DRO schedule) or non-resetting delays (either chain or tandem schedules in which the final component is either a FT or VT schedule) (Pierce, Hanford and Zimmerman, 1972). It is Schoenfeld et al's (1973) and Schoenfeld and Cole's (1972) view that a response-independent reinforcement schedule is most similar to the unsignalled non-resetting delay of reinforcement schedule.

Transferring an organism from an immediate reinforcement schedule to a delayed reinforcement schedule results in response decrement (Pierce et al, 1972; Renner, 1964; Rescorla and Skucy, 1969: Richards, 1981: Sizemore and Lattal, 1977; Williams, 1976). There are occasional reports of response rate increases when such transitions are made, these all being limited to cases where unsignalled, non-resetting delays of very short programmed duration are used (Lattal and Ziegler, 1982: Richards, 1981; Sizemore and Lattal, 1978). Lattal and Ziegler (1982) have attempted to isolate the variables responsible for this response-incrementing effect. They added a delay of 0.5 sec onto both a DRL and VI baseline. IRT distributions revealed that those cases in which response-increment occurred were correlated with an increase in the relative frequency of reinforced short IRTs over baseline. Such an increase in the relative frequency of short IRTs may not necessarily be

accompanied by an increase in response rate. This possibility exists because it may be balanced by an increase in the relative frequency of long IRTs as compared to baseline, i.e., the middle range IRTs become relatively less frequent. Unfortunately, those studies which have found a response rate increase during response-independent reinforcement conditions have not reported their data in the form of IRTs (Lachter et al, 1971; Lattal and Bryan, 1976; Lattal and Boyer, 1980; Zeiler, 1979b). Davis et al (1973), however, presented some of their data in the form of IRT distributions. It was clear that response decrement during the VT condition was associated with an increase in the relative frequency of long IRTs compared to the baseline DRL condition. Long IRTs imply that ~~R~~ is relatively more frequent than R in the behaviour stream. Interestingly, Lattal and Ziegler (1982) interpret their results within a contiguity framework.

Delayed reinforcement and response-independent reinforcement can be compared in terms of other behavioural phenomena. Data from multiple schedules provides a rich source of information. Exposing organisms to multiple schedules in which the different components are associated with different rates of reinforcement yields a number of by-products. Three of these are of interest here. These are behavioural contrast (an increase in response rate in the unchanged component accompanied by a decrease in response rate in the changed component); excitatory gradients around S+ and inhibitory gradients around S- when the stimuli are from

orthogonal dimensions; and the emergence of the peak shift when the stimuli (S+ and S-) are from the same physical dimension (Rilling, 1977; Terrace, 1972). Transferring an organism from a mult VI VI to a mult VI VI+delay (or mult RI RI to mult RI RI+delay) is sometimes correlated with the emergence of positive behavioural contrast. This is only the case when the delay is signalled (Richards, 1972; Richards and Hittesdorf, 1978). Where the delay is of the non-resetting unsignalled variety, it is more likely that induction will be observed (Richards and Hittesdorf, 1978; Wilkie, 1971).

In those experiments in which generalization gradients were measured, it is typically found that the stimulus dimension associated with delayed reinforcement yields an inhibitory gradient while that associated with immediate reinforcement yields an excitatory gradient (Richards, 1973; Richards and Hittesdorf, 1978; Richards and Marcatillio, 1978). When the discriminative stimuli associated with immediate and delayed reinforcement come from the same dimension, a peak shift (positive - away from the stimulus associated with delayed reinforcement) emerges (Wilkie, 1972). In the case where component schedules of a multiple schedule are delayed reinforcement and extinction respectively, the stimulus associated with the delayed reinforcement is associated with an excitatory gradient (Richards and Marcatillio, 1978).

When response-independent reinforcement has been contrasted with immediate response-dependent reinforcement within a

multiple schedule format, the results are very similar to those which have been observed when the schedules are delayed versus immediate reinforcement. For example, Boakes (1973), Halliday and Boakes (1972) and Halliday and Boakes (1971) all failed to find contrast when the transition made was from mult VI VI to mult VI VT (see also Gutman, 1977 Weisman and Ramsdem, 1973). Instead an induction effect was observed. When the VT reinforcer was signalled, however, a strong behavioural contrast effect emerged (Marcucella, 1976). When stimulus generalization gradients have been assessed, the results have been somewhat mixed. Weisman and Ramsden (1973) found inhibitory gradients around the stimulus associated with the VT schedule, but only when fairly extensive nondifferential training had been given. Halliday and Boakes (1971), however, found inconclusive results after mult VI VT training. One of the problems in these experiments is that the generalization testing is often carried out in extinction. When this is compounded with testing a VT stimulus in the presence of which the tendency to respond is weak, the relatively flat gradients may not be a sign of a lack of inhibition. Rather, they could reflect a floor effect. In line with this view, is the finding that when the combined-cue and resistance to reinforcement assays (Hearst, Besley and Farthing, 1970) are used, an inhibitory gradient around the VT stimulus has been obtained (Gutman, 1977). Exposure to mult VI VT training, where the discriminative stimuli are on the same dimension has been found to yield a peak shift (Huff, Sherman and Cohn, 1975). In addition, Huff et al (1975) also found

evidence for a secondary peak (i.e., between the S+ and S-). Such secondary peaks are rare, but have been reported in the literature, especially where both components of a multiple schedule are associated with some sort of positive reniforcement (i.e., as long as extinction does not occur in one of the components) (Wheatley and Thomas, 1974). Finally, in those cases where the component schedules involve a contrast between a response-independent reinforcement schedule and extinction, it is likely that the stimulus correlated with response-independent reinforcement will acquire excitatory properties (Redford and Perkins, 1974).

Taken as a whole, these data present a remarkably consistent picture. In the context of multiple schedules, response-independent reinforcement has the same effects as an unsignalled variable delay of reinforcement schedule when each is contrasted with an immediate reinforcement schedule. Particularly compelling is the data relating to behavioural contrast; that phenomenon only emerges in the case where either the response-independent reinforcer or the delayed reinforcer is signalled. These data, then, provide strong support for the analysis of schedules of reinforcement provided by Schoenfeld et al (1973) and Schoenfeld and Cole (1972).

A much stronger prediction from the theory proposed by Schoenfeld et al (1973) is that response-decrement need not accompany the transition from a response-dependent

reinforcement schedule to a response-independent one. Further, response maintenance is most likely to be observed where the baseline schedule is an unsignalled variable delay of reinforcement schedule. Schoenfeld et al (1973) have examined this possibility. They exposed pigeons to a multiple delay of reinforcement schedule. The component schedules were based upon the kind of schedules specified by the t-tau systems (Schoenfeld and Cole, 1972). The schedules were arranged as follows. A recycling time period (T) was selected. If a response occurred during any part of that time period, reinforcement was presented at the end of the cycle with a probability of 1. The nearest equivalent to a schedule in the Ferster and Skinner (1957) scheme is a tand FR1 VT schedule. They used a 4-ply multiple schedule in which the T values were 15, 30, 60 and 120 sec. Once responding was reliably occuring in <u>each</u> T cycle, the pigeons were exposed to a multiple schedule in which the necessity to respond was removed (i.e., mult FT15 FT30 FT60 FT120 sec). The baseline schedule was kept in effect for between 52 to 56 sessions, while the response-independent reinforcement schedule was maintained for between 55 and 67 sessions. One bird was exposed to a single value delay schedule in which the T value was 15 sec and the p value was 1. This bird was then switched to a FT15 sec schedule. Both the response-dependent and response-independent phases were in operation for 31 sessions. There were no signalling exteroceptive stimuli present for this bird. The results indicated that responding was well maintained for all animals; there were no cases of response decrement, indeed,

response-independent reinforcement was often associated with response increment. There was an inverse relation between T value and response rate in both phases of the experiment. These data appear to provide strong support for the position advanced by Schoenfeld et al (1973). They are open to the criticism that Schoenfeld et al (1973) have selected procedures in which response maintenance was most likely to occur. In the multiple schedule format, there were differential stimulus-reinforcer contingencies. Such contingencies are likely to lead to maintained responding, especially when the subjects are pigeons (McSweeney, 1977). Further, the response-independent reinforcement schedules were FT schedules. The T value selected for the pigeon exposed to the single schedule condition was well within the range in which maintained responding has been found, even when the transition is from an immediate response-dependent reinforcement schedule (Lowe and Harzem, 1977). Thus the maintained (and possibly enhanced) rate of responding observed by Schoenfeld et al (1973) could be due to either one or both of these variables.

Evidence from other sources concerning this kind of transition provides only patchy support for Schoenfeld et al's (1973) hypothesis. Sizemore and Lattal (1977) exposed pigeons to a tand VI FT schedule in which the VI parameter was either 60 or 63 sec and the FT parameter was either 3 or 6 sec. The birds were then transferred to either a VT60 or 63 sec schedule. In addition, two of the three birds were exposed to a transition from a VI to a VT schedule. They

found considerable response decrement after both immediate and delayed reinforcement. For one of the two birds, response decrement was more severe after the immediate reinforcement schedule relative to the delayed reinforcement schedule, while the reverse was the case for the other bird. These results are in conflict with Schoenfeld et al's (1973) hypothesis. There are a number of differences between these studies. First, the maximum possible delay in the Sizemore and Lattal (1977) experiment was much shorter than those values used by Schoenfeld et al (1973). Some of Sizemore and Lattal's (1977) data indicate that longer programmed delays may create better conditions for maintained responding (see Bird 10). Second, reinforcement frequencies were not matched across conditions in the experiment reported by Sizemore and Lattal (1977). Rate of reinforcement was in fact higher during the VT phase relative to baseline. When rate of responding is low during the baseline, such increases in rate of reinforcement are likely to lead to the additional reinforcers contacting R. The actual baseline rates observed by Sizemore and Lattal (1977) were between 9.3 and 27.1 responses per minute. To make the experiments comparable, we would have to know whether responses occurred on the baseline delay schedule with a sufficient frequency such that at least 1 response occurred within the minimum IRI used by Sizemore and Lattal (1977). They do not provide the distribution of IRIs which constituted their baseline schedule (note that Schoenfeld et al, 1973 were careful to observe that a response occurred in each T-cycle of their schedule). When the rate of

responding was only 9.3 responses per minute, however, it is unlikely that the constraint observed by Schoenfeld et al (1973) was in fact achieved. A third difference between the studies is the absence of differential stimulus-reinforcer contingencies in that reported by Sizemore and Lattal (1977). Finally, the delays of reinforcement during the VT condition were longer than those observed during the baseline delay schedules. Any one of these variables could account for the difference in the results observed in these studies.

Catania and Keller (1981) transferred pigeons to a series of VT schedules (either VT10 or 20 sec) after exposure to the following conditions:- VR20, tandVR13.3 VT4 sec, tand VR13.3 FT5 sec and tand VI10 sec VT5 sec. In some conditions, the delay schedule was programmed such that IRIs could occur without a response. They also examined the transition from extinction to both VT10 sec and tand VI10 sec VT10 sec. The transitions from VR20 to VT10 sec have been discussed in section 2.4. Congruent with the majority of other studies, transition from VR20 to various delay of reinforcement schedules was correlated with response rate reduction. Of interest here, though, are the transitions from the delay schedules to the VT schedules. In most cases this transfer was associated with response decrement. In those cases where response rate under the delay schedule was in the region of 80 responses per minute, responding was well maintained. Overall, Catania and Keller's (1981) data do not confirm Schoenfeld et al's (1973) results. Catania

and Keller (1981), however, do not match rate and temporal distribution of reinforcement across the response-dependent and independent phases. For example, two birds were initially exposed to a tand VR13.3 FT5 sec schedule. They were then exposed to a VT 10sec schedule. The latter schedule was programmed by use of a recycling timer (set at 1.00 sec) and a probability generator set at 0.1. Thus the minimum IRI on the VT schedule was 1.0 sec. The minimum IRI on the delay schedule was 5sec. The mean rate of responding at the end of the baseline condition was 36 and 58 responses per minute for the respective birds. Quite clearly, such low rates during the baseline would not be associated with a reinforcement rate of 6 per minute. The discrepancy between minimum IRIs, however, is probably more serious, because this would allow IRIs without a response to occur during the VT schedule. It is unfortunate that Catania and Keller (1981) have programmed their VT schedules in this manner (their VT20 sec was programmed by using a T of 1 sec and a p of 0.05); the same reservations which were expressed concerning the procedures used by Sizemore and Lattal (1977) are relevant here too. Catania and Keller (1981) also provide data on the contiguities between responding and reinforcement. They found that the VT schedule was associated with a greater proportion of response-reinforcer contiguities (operationally defined as being less than 0.33 sec) during the first 10 sessions during VT10 sec relative to the preceding delay schedules. This kind of result is problematic for the contiguity view. It has to be noted though that during the VT sessions IRIs without a response

occurred, i.e., X was selectively reinforced. The relationship between IRIs without a response and delays of reinforcement has yet to be assessed. It may be the case that the former are able to overshadow occasional contiguities.

Although Catania and Keller (1981) do not dispute the reality of superstitious conditioning or that single reinforcers can have marked effects on the behaviours with which they are contiguous, they do argue that such effects are short-lived. "Instead organisms must be able somehow to integrate events over time and to respond on the basis of correlations among reinforcement rates and response rates. But they must also make contact with other simpler schedule dimensions correlated with contingencies." (Catania and Keller, 1981, p162). It is their view that the discrimination of response-dependency from response-reinforcer independence is a function of a number of variables such as the distribution of response-reinforcer intervals, IRIs without a response as well as the integration of various rates, delays and correlations of events over time. Such a view is close to the correlation view (Baum, 1973). Catania and Keller (1981), however, appear to suggest that the integration of events over time is partly determined by molecular variables.

Taken as a whole, the data relating to Schoenfeld et al's (1973) theory are rather mixed. There is no doubt that delayed reinforcement and response-independent reinforcement

can have dramatically similar effects when each is contrasted with immediate reinforcement. The research on direct transitions from a delay of reinforcement baseline to response-independent reinforcement, however, is less convincing. Only the data provided by Schoenfeld et al (1973) unequivocally supports their position. The data are open to other interpretations. Although the theory can explain the discrepant results which have been found by both Sizemore and Lattal (1977) and Catania and Keller (1981), the theory is in need of a set of data for which other interpretations might be less compelling. Data based upon experiments in which there are either differential stimulus-reinforcer contingencies or FT schedules or both cannot be regarded as supporting the contiguity position.

2.6.2. The Correlation View

Although the correlation view is the main alternative to the contiguity view in this area, there is no definitive account of its application to studies of response-independent reinforcement comparable to Schoenfeld et al's (1973) articulation of the contiguity position. The correlation view is one variant of the molar position outlined in section 1.3.2.2. It has been most fully developed by Baum (1973), and I shall follow his exposition. Other major spokesmen for this theory are Rachlin (1976) and Killeen (1978). Baum (1973) proposes that the behaviour of an organism is a function of two kinds of feedback. These are the environment-output feedback loop and the response-effort feedback loop, both loops being closed. The correlation

view has made its main contribution by examining the former of these feedback loops. It departs from both the contiguity and contingency views (Williams, 1983) in its focussing on events over time rather than discrete instances of such events (e.g., specific responses or reinforcers). The essential point of the correlation theory is that it proposes that organisms sample the rate of occurrence of events over time. They then integrate and relate these to each other (i.e., they correlate them - "Whichever variable controlled performance the pigeons performed the equivalent of a statistical test of significance." Baum, 1981, p255). Given the view that organisms sample events over time, the counting of discrete responses or reinforcers is of little consequence. Rate of responding and rate of reinforcement are the primary measures. Baum (1973) adopts a view which is similar to that expressed by Staddon and Simmelhag (1971) with regard to response-independent reinforcement. He notes that "In the present context, such non-correlation procedures (i.e., autoshaping and classical conditioning) omit feedback. They are open-loop systems. Since this paper concerns the law of effect, it is limited to consideration of the effects of procedures that impose a correlation between behaviour and reinforcement . . ." (Baum, 1973, p141). Essentially then the principles of behavioural variation are operative here rather than the principles of reinforcement. Nevertheless, response-independent reinforcement is usually applied after there has been a correlation between responding and reinforcement. Thus a positive correlation is replaced by a zero

correlation, and Baum's (1973) theory would make predictions in such a case. Response-independent reinforcement degrades the correlation between the measured response and reinforcement. Rate of responding is therefore likely to be adversely affected. A similar reasoning holds for the transition from immediate reinforcement to delayed reinforcement. There is a major difference between delayed reinforcement and response-independent reinforcement, however. Baum (1973) notes that, although response elimination may occur under response-independent reinforcement, it does not do so under delayed reinforcement - and this is especially so when IRIs are equal. To obtain response elimination under delayed reinforcement, one would have to use very long delays, in which case such a schedule approximates an extinction schedule rather than a response-independent one. Note here though that although responding can be eliminated by a DRO schedule, such a schedule arranges a positive correlation between ~~R~~ and reinforcement; Baum (1973) would predict response elimination in this case. Baum's (1973) comments concerning delayed reinforcement are based on his view of the relation between contiguity and correlation. Contiguity is successful in maintaining high response rates because it guarantees a positive correlation between responding and reinforcement.

Interestingly, Baum (1973) would make a similar prediction regarding the transition from a delay of reinforcement to a free reinforcement schedule that Schoenfeld et al (1973) make. That is, that response decrement would be slower

relative to the transition from an immediate reinforcement schedule to a response-independent one. The reason for this is that it would be more difficult for the organism to discriminate the lack of correlation between response and reinforcer under the former arrangement relative to the latter, i.e., it is more difficult to discriminate between a low but positive correlation between response and reinforcer (or, better their rates) and a zero correlation than it is to discriminate between a high and a zero correlation. Where no response decrement occurs after a transition to response-independent reinforcement, a failure to discriminate between the conditions has occurred (Rachlin, 1976).

The correlation view can quite adequately explain most of the results reviewed in sections 2.3 and 2.4. Response maintenance under FT schedules is accounted for on the basis of the principles of behavioural variation. Where no difference occurs between response-dependent and response-independent schedules in terms of response rates and VT schedules have been used (e.g., Lattal, 1973), the reason is due to a lack of opportunity to discriminate between the conditions. In Lattal's (1973) data, response decrement occurred under the mixed schedule when the duration of the components was lengthened. This of course provides the organism with a longer time sample (a contiguity theorist would maintain that such a manipulation allows for an increased opportunity for the reinforcer to contact ~~R~~). The data reviewed in section 2.5 is somewhat more problematic

for the correlation view and will be reviewed in a subsequent section (section 2.6.2.1).

In order to examine the role of response-independent reinforcement, correlation theorists have adopted a strategy which is different from that used by contiguity theorists. Essential to the correlation view is that organisms are able to discriminate between conditions under which rate of responding and rate of reinforcement is correlated from those under which they are not. Therefore they have carried out experiments in which the organism is required to discriminate between schedule conditions. The experiments have been designed to exclude recourse to either contiguity mechanisms or other molecular cues (Baum, 1981). It should be noted that Baum (1973) has consistently stated that it is difficult to design experiments which unconfound response-reinforcer contiguity and response-reinforcer correlation. Nevertheless, attempts have been made and these will now be reviewed.

2.6.2.1. Discrimination of Correlations

There is evidence to suggest that organisms are able to discriminate between different schedule conditions (i.e., response-reinforcer correlations) (Lattal, 1981). Of major concern though, is the means by which they achieve these discriminations. If the use of molecular cues is responsible for the discriminative performance, then such discriminations do not provide unequivocal support for the correlation view (Baum, 1981).

Hammond (1980) exposed rats to a schedule in which the probability of reinforcement for the presence and absence of a response was varied. Specifically, Hammond (1980) used a 1 sec recycling time period, and assigned varying probabilities of reinforcement according to whether there had been either a response or no response during that time period. In some cases, the probability of reinforcement for $\not R$ was kept constant at 0 ($P_{RFT/\not R} = 0$) while that for a response was varied from 1, 0.2 to 0.05. Of interest here was the transition from the case where $P_{RFT/R} = 0.05$ and $P_{RFT/\not R} = 0$ to the case where $P_{RFT/R} = P_{RFT/\not R} = 0.05$. Hammond (1980) found that a positive correlation between responding and reinforcement maintained responding. Further, the higher the correlation (i.e., the greater the discrepancy between the probabilities for response occurrence and nonoccurrence) the higher the response rate. Where the probabilities were equal (i.e., a zero correlation) responding declined rapidly. This constitutes strong support for the correlation view. Note, however, that in the zero correlation case, the schedule is very similar to one in which a DRO is superimposed upon a RI schedule. Such an arrangement is very likely to lead to response decrement (e.g., Henton and Iversen, 1978; Rachlin and Baum, 1972). This type of result is not beyond a contiguity-based explanation.

Baum (1981) exposed pigeons to a mixed schedule in which one component was a conjunctive FR1 VT schedule and the other

was a conjunctive DRO VT schedule. The VT parameter was varied from 5 to 30 sec. Baum (1981) argued that any discriminative performance would have to be due to a discrimination between the response-reinforcer correlations represented by the different component schedules. Baum (1981) represented his data in terms of a discrimination index which was based upon relative response rates in each component. He found a good discrimination between the components. Further, the discrimination was most accurate at low VT values. This is in line with molar theory because ease of discrimination is related to rate of reinforcement. Specifically, as the reinforcement rate decreases any molar features which the organism can use to distinguish between the two components become more variable. His results, however, can be accounted for in terms of differential delays to reinforcement. Baum (1981) notes that "Although the delays differed in central tendency (median) from the DRO to peck component, sometimes by a factor of twenty to one, the frequency distributions always overlapped." (Baum, 1981, p255). It can be proposed that Baum's (1981) birds were actually exposed to successive conditioning-extinction episodes. For example, on transferring from a peck component to a DRO component, responding is extinguished, giving rise to some other behaviour. The bird is then transferred to the peck component and R is now extinguished. During extinction, behaviours which have been absent from the behaviour stream often reappear (Schoenfield et al, 1973). It is therefore probable that pecking will re-emerge. Such episodes of pecking are then followed by

reinforcement, albeit at some variable delay. These results can therefore be explained by traditional molecular variables.

Killeen (1978, 1981) has attempted to analyse the pigeon's perception of causality. The birds were exposed to a three-key procedure in which the middle key was illuminated. Pecks produced by either the pigeon or simulated by a computer could extinguish the light on the middle key and cause the side keys to be lit. The task for the pigeon was to report whether its pecks or a computer 'peck' had turned off the lighted middle key. The bird could do this by pecking one of the side keys. The pigeons learned this discrimination to a reasonably high level. Killeen (1981) presented data which suggested that the pigeons mastered the discrimination on the basis of differential delays from a peck to stimulus change. Some of the birds acquired quite stereotyped patterns of behaviour - execution of these behavioural sequences often satisfied the contingencies (see Killeen, 1981). Killeen (1978) also manipulated reinforcer magnitude. This manipulation led to an increase in the probability of a 'false alarm' (Killeen, 1978 analysed his results in terms of signal detection theory). Such a tendency was labelled 'bias' and is possibly due to motivational variables. Killeen (1981) discussed the implications of these results for the notion of superstitious conditioning. He notes that "Response-incentive contiguity is important, but its effects cannot be understood without reference to the relative payoffs for

other responses. There is no such thing as the delay of reinforcement: there is a family of gradients whose parameters are the values of the organism's criterion." (Killeen, 1981, p104) - his emphasis. If mention of the term 'organism's criterion' were dropped then Killeen's view is fairly close to that proposed by Schoenfeld et al (1973). Killeen (1981), however, is clear in rejecting the notion of superstitious behaviour. His view is that such behaviour is determined by what the animal 'knows' (can detect) and what it wants (bias). Superstitious behaviour is contrary to evolutionary pressures, because it implies a waste of energy. His own data, however, do not preclude such a mechanism, as Baum (1981) has noted.

Although these experiments do not provide unequivocal support for the correlation view, they also do not conflict with it. Other data, however, are more critical. Williams (1976) has reported two experiments in which birds were exposed to a VI schedule. They were then formed into groups of pairs, where one member of the pair was exposed to an unsignalled variable delay of reinforcement (tand VI FT), while the other was yoked to it. All pigeons performed both roles and the delay parameter was varied. He found that both the delay schedule and the yoked VT were associated with response decrement relative to the VI baseline. Rates during the delay and VT schedules were comparable in experiment 1; but not in experiment 2 where the delay schedule (parameter of 5 sec) was associated with the higher rate. At this level of analysis, the data appear to support

the correlation view. Williams (1976), however, conducted a more detailed analysis. He points out that response rate during both the delay and VT schedules was highly variable. Sometimes, cyclicities of unequal periodicity were apparent. It is difficult to explain this on the basis of a correlation account, especially where response rate increases follow rate decreases during the VT condition where the putative response rate - reinforcer rate correlation is zero. Further, although the yoked group responded at a lower rate during the second experiment relative to the delay 'masters', such a comparison is inappropriate because the yoked birds VT schedule was not matched to their own prior response-dependent reinforcement schedule, and response-dependent reinforcement baseline performances varied widely between birds. Williams (1976) attempted to calculate the size of the time sample used by the birds for their computation of the correlation between rates of responding and reinforcement. This exercise yielded different time samples for each different delay parameter. He concluded that "It is apparent, therefore, that to account for the data produced by the different delay conditions of Experiment I, the size of the temporal sample must be free to vary across conditions. Such an assumption seems highly implausible, because the temporal sample presumably should be a fixed property of the pigeon that should be constant across experimental conditions . . . (I)t is possible that the organism uses not just a single size of temporal sample, but a distribution of samples, which in turn might be differentially weighted in the computation of

the correlation coefficient. Once such concessions are made, however, the concept of correlation ceases to be empirically testable." (Williams, 1976, p448). Williams (1976) states his preference for a contiguity-based account in this context.

In two similar experiments, Smith and Clark (1972) and Thomas (1981) have presented data which are critical of the correlation view. Smith and Clark (1972) exposed rats to a Sidman-type schedule in which food was the reinforcer rather than shock avoidance. If the rats did not press the lever, they were exposed to FT schedules the t value of which was 30 sec, 60 sec or 10 min. If they responded, however, a response-food (R-F) interval was set up. The R-F interval varied from 0 (continuous reinforcement) to 90 sec (in the FT 10 min condition) or to 30 or 60 sec in the FT30 and FT60 sec conditions respectively. In another condition, the R-F interval was held constant at 30 sec while the FT schedule was varied from 5 to 120 sec. Responses during the R-F interval reset the interval. Of interest here are those conditions in which R-F = FT (a zero correlation) and where R-F exceeded the FT value (negative correlation). The results indicated that response rate was a declining function of R-F interval duration. In the first part of the experiment, response rate decreased to zero when R-F = FT. In the second part (where R-F was held constant), however, responding was maintained when the R-F interval was equal to the FT value. For one of the two rats studied, responding was maintained when the correlation was negative, i.e., when

R-F interval = 30 sec and the FT schedule was FT15 sec. Thomas (1981) has reported a similar set of data. In his experiment rats were exposed to a FT20 sec schedule. The first response during the FT interval was reinforced immediately, but cancelled the FT reinforcer (i.e., the FT was replaced by a FI20 sec schedule). Under these conditions, the lever press response was both acquired and maintained. In a second experiment, Thomas (1981) retained the same arrangement except that the reinforced response both cancelled the FT reinforcer and postponed the start of the next interval. Thus responding was correlated with a decrease in the overall rate of reinforcement, i.e., was negatively correlated with rate of reinforcement. Under these conditions, lever pressing was once more acquired and maintained. The results from both of these experiments are difficult to explain according to correlation theory. Thomas (1981) proposes a number of ways in which the correlation view might be able to explain his results. None of these are successful, however, because they involve either resorting to implausible assumptions or making recourse to molecular variables. The implication seems to be that correlations are based upon observed or obtained response-reinforcer contiguities, rather than contiguities being secondary to response-reinforcer correlations.

A fourth set of data which cast doubt on the correlation view is that concerned with superimposing free reinforcers upon a response-dependent reinforcement baseline. Although the early research in this area supported the correlation

view (Rachlin and Baum, 1972), more recent research is more problematic (Lattal and Boyer, 1980; Lattal and Bryan, 1976; Zeiler, 1979b). The reason for this is that either no response decrement or response increment occurs when free reinforces are introduced. Where no response decrement relative to baseline occurs, the correlation view can make recourse to an inability to discriminate between the baseline and response-independent reinforcement phases (Rachlin, 1976). The major problem comes in attempting to account for response increment. It cannot be the case that the organism cannot discriminate between the conditions; for, if response decrement indicates a discrimination (Baum, 1981), then a response increment above baseline must do likewise. The correlation view could explain the response increment observed in these experiments by proposing that the free reinforcers happen to intercept a time sample in which responses were being emitted at a rate higher than that normally maintained on the baseline. This, however, is merely restating a molecular contingency in correlation terms. It is really no different from making recourse to an adventitious reinforcement notion.

It seems appropriate to conclude this section by quoting Williams (1983). " . . . (T)he important point to note is that correlational analyses of conditioning make the strong claim that superstitious conditioning is not a legitimate concept. Convincing demonstrations of the reality of such conditioning should thus go far in vitiating the correlational approach." (Williams, 1983, p76). The above-

mentioned data provide reasonable grounds for proposing the reality of the effectiveness of adventitious reinforcement in changing behaviour (see also Henton and Iversen, 1978).

2.7. Contiguity and Correlation

The two major explanations of response-independent reinforcement have now been reviewed. It is clear that, although both views can explain much of the data, there is as yet no satisfactory set of results which provide conclusive support for either one or the other theory. The contiguity view as proposed by Schoenfeld et al (1973) lacks a clear data base. Many of the results which have been accounted for on the basis of contiguity theory have not compelled such an explanation (e.g., Lachter, 1971; Lachter et al, 1971). The majority do not exclude an explanation in terms of correlations. More often than not, the data has been presented in terms of means from a number of sessions. Such a metric is far too gross - indeed, such a measure is a molar one, when more molecular measures are required. The data on the transfer from delay of reinforcement to response-independent reinforcement provide only slim support for this theory. Although the contradictory data (Catania and Keller, 1981; Sizemore and Lattal, 1977) can be explained by this theory in terms of discrepancies between the temporal distribution and rates of reinforcement phases, such explanations are often post hoc, and do not exclude alternative interpretations, including the correlation hypothesis.

The correlation theory hardly fares better. There are data which directly contradict the theory (Lattal and Boyer, 1980; Lattal and Bryan, 1976; Thomas, 1981; Zeiler, 1979b). Further, it is difficult to operationalize at least one of the independent variables of which behaviour is supposed to be a function (i.e., the time sample upon which response rate - reinforcement rate correlations are calculated) (Thomas, 1981; Williams, 1976). The experiments reported herein are designed to re-examine some of the problems posed by response-independent reinforcement. They have been guided in the main by the theory proposed by Schoenfeld et al (1973). This theory was chosen because it has been articulated in a more detailed fashion than the correlation view, when this area of research is considered. Further, unlike the correlation view, there are no data which directly oppose it. The experiments are an attempt to isolate the variables of which maintained responding during VT schedules is a function. In the spirit of the experimental analysis of behaviour, schedules of reinforcement provide the experimental context (Ferster and Skinner, 1957).

In the next chaper, the rationale underlying the experiments is outlined and some data from pilot experiments are presented.

CHAPTER 3 RATIONALE AND PILOT EXPERIMENTS

3.1. Rationale

The general aim underlying the experiments to be reported here is to examine the effects of response-independent reinforcement on the probability of occurrence of a response previously maintained by a response-dependent reinforcement schedule. More specifically, the experiments were designed to assess the validity of Schoenfeld et al's (1973) view that response-independent reinforcement need not be correlated with response decrement. As noted in section 2.6.1., one of the most interesting predictions made by Schoenfeld et al (1973) is that resistance to the response-decrementing properties of response-independent reinforcement will be increased when the baseline response-dependent reinforcement schedule is one which involves a variable delay contingency rather than one which ensures immediate reinforcement. It is this prediction which is most closely examined.

The review of literature revealed a number of procedures which it would be unwise to use where one is attempting to assess the role of response-reinforcer dependency in response maintenance. Schedules which involve the use of differential stimulus-reinforcer contingencies are an example of such procedures. These kinds of schedules (e.g., multiple schedules) are likely to lead to either response or reinforcement interactions such that any effect of removing a response-reinforcer dependency would be confounded with these interactions. A second procedure which was excluded

was the use of FT schedules. The reason for this is that this kind of schedule is likely to induce stereotyped food-related behaviours which may interfere with the effects of either removing or degrading a response-reinforcer dependency. This leaves available two kinds of procedures. The first is the case where there is a direct transfer from a response-dependent to a response-independent reinforcement schedule. The second is where response-independent reinforcers are superimposed upon a response-dependent reinforcement baseline. I have opted for the former procedure. The reason for adopting this strategy is that the distinction between response-reinforcer dependency and independency can be more clearly examined in this situation because the two arrangements are kept apart. In the latter arrangement (i.e., superimposition), the interactions between the two methods of delivering the same kind of reinforcer ae potentially very complex.

3.2. Pilot Experiments

The pilot experiments were aimed at providing a partial replication of Schoenfeld et al's (1973) experiment 2. In the two experiments to be reported, however, differential stimulus-reinforcer contingencies were excluded. In addition, the probability of reinforcement parameter was changed so that the response-independent reinforcement schedule approximated a VT schedule rather than a FT schedule. Finally, rat subjects were used.

3.2.1. Experiment 1 - Transfer from an unsignalled variable delay of reinforcement schedule to a VT schedule.

Method

Subjects

Two male hooded rats maintained at 80% of their normal body weights served as subjects. They were about 6 months of age at the beginning of the experiment. They were individually housed and ad lib water was available in their home cages. Neither had any experience of operant conditioning tasks.

Apparatus

One 2-lever Grason-Stadler rat chamber (Model 1111P) which was housed in a Grason-Stadler sound attenuating chest (Model 1101). Only the left lever was operative, the right one having been removed. Located 4 cm to the left and 1 cm above the lever was a green 12.6v cue light which, along with a 12.6v, 2w incandescant house light located in the front top left hand corner of the chamber, was continuously illuminated throughout all experimental conditions. Masking noise and ventilation were provided by use of a fan which was housed in the sound attenuating chest. Events were programmed by a hybrid system of Grason-Stadler Series 1200 solid state modules interfaced with Campden Instruments relay equipment. Reinforcement consisted of 45 mg Campden Instruments food pellets.

Procedure

The rats were shaped to lever press by use of the method of

successive approximations. Once shaped, they were left in the chamber and allowed to obtain about 50 reinforcements on a continuous reinforcement schedule. During the next 3 days, they were exposed to an ascending series of FR schedules which culminated with a value of FR8. They were then exposed to a variable delay of reinforcement schedule. This was programmed as follows. A recycling time period (T) was selected. A lever press during T gated the output of the recycling timer to a probability generator. The output of this delivered the reinforcer without the necessity for a further response. Delivery of the reinforcer broke the connection between the recycling timer and the probability generator and it was not reconnected until another response occurred. Thus, in the absence of any responding no reinforcers would be dispensed, but only a single response was necessary to produce a reinforcer. Therefore, this schedule ensured that the animal could be doing something other than emitting the designated response when the reinforcer was delivered. The initial T and p values were 10sec and 0.8 respectively. These were reduced to the final baseline value of T = 5sec, p = 0.2. In this schedule, the minimum IRI is 5sec, while the maximum is infinity. Given that the animal responded in each T cycle, the average IRI is 25sec (T/p). Response-independent reinforcement was programmed by removing the necessity for a response-occurrence. The T and p values were initially the same as those obtaining during the baseline condition. Rate of response-independent reinforcement was then varied. Schedule conditions and the number of sessions under each

schedule condition are detailed in Table 3.1. The rats were run on 5 days per week and session duration was 1 hour.

TABLE 3.1

Schedule order for Experiment 1

	Rat 1			Rat 2	
	Schedule	Sessions		Schedule	Sessions
A	Delay	55	A	Delay	55
B	T=5sec, p=0.2	15	B	T=5sec, p=0.2	15
C	T=3sec, p=0.2	2	C	T=7.5sec, p=0.2	13
D	T=3sec, p=0.1	7			
E	T=7.5sec, p=0.1	3			

Results and Discussion

Responses per minute during the last 5 sessions of the delay condition and all sessions of the response-independent reinforcement conditions are shown in figure 3.1. The transition from the delay schedule to response-independent reinforcement was associated with a decline in response rate. The decline, however, takes a cyclical form (see also Williams, 1976). By the last 7 or 8 sessions in condition B, response rate seems to have stabilized (c.f. Herrnstein, 1966). Changing the frequency of response-independent reinforcement had surprising (c.f., Lachter et al, 1971) but systematic effects. Decreasing the rate of response-independent reinforcement for Rat 2 was correlated with an immediate decrement in response rate, but this then recovered and eventually reached levels which were in excess

of those prevailing during the last 5 sessions of the previous response-independent reinforcement condition. Changes in both T and p parameters had marked effects on Rat 1's performance. Decreasing T and therefore decreasing the mean and minimum IRI as well as increasing the rate of reniforcement resulted in a rapid decline in response rate. Decreasing the p parameter was correlated with an immediate recovery in response rate (this manipulation alters the mean IRI but not the minimum IRI) which was maintained at levels comparable to those observed during the initial exposure to response-independent reinforcement. Increasing T produced a transient increase in response rate. Changes in rate of responding during the response-independent reinforcement conditions, therefore are lawfully related to changes in the T and p parameters.

The results are in broad agreement with Schoenfeld et al's (1973) findings. The response decrement observed during the initial transition to the VT schedule (or RT schedule) can be accounted for on the basis of the discrepancy between reinforcement rates under the response-dependent and response-independent reinforcement conditions (i.e., conditions A and B). Although programmed rates were the same, obtained rates of reinforcement were higher during the VT condition. The percent of T cycles in which there was a response during the last 5 delay sessions was 41.3 for Rat 1 and 51.3 for Rat 2. Given that the rats did not respond throughout the T cycle, it can be deduced that they allocated more time to emitting $\not{R}$ relative to R. Therefore

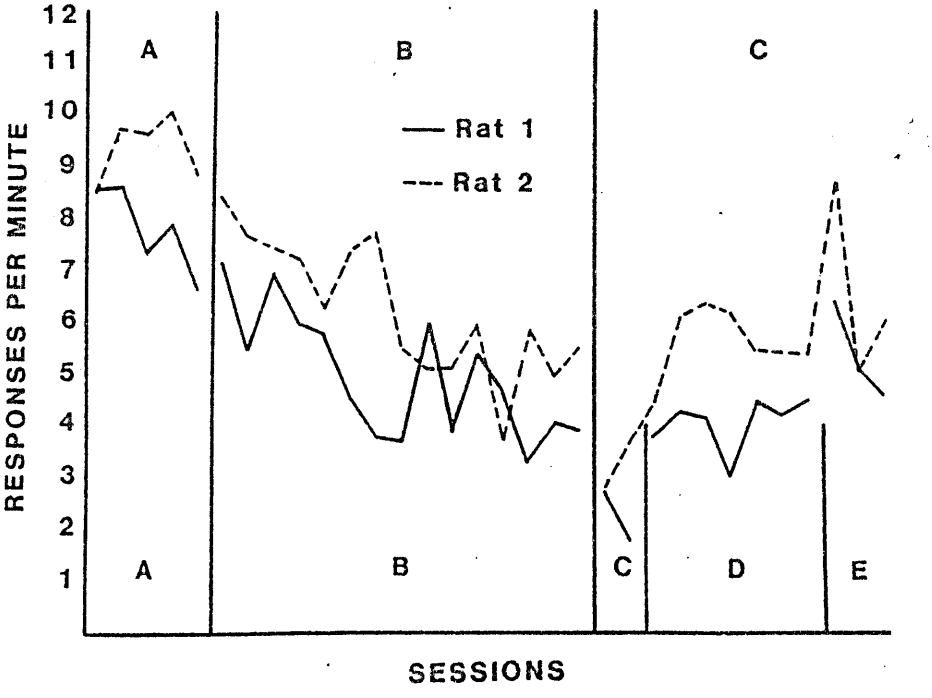


Fig. 3.1. Rate of responding during the last 5 sessions of baseline and each session of response-independent reinforcement. Capital letters refer the different experimental conditions.

the extra reinforcers would be more likely to contact X rather than R.

Although both maintained responding under a VT schedule and modification of response rate by variation in the rate of response-independent reinforcement has been demonstrated, these results must be regarded as being only suggestive. There was no immediate reinforcement control condition and conditions C, D and E were implemented off different baselines. The next pilot experiment tested the prediction that resistance to response-independent reinforcement would be stronger where an unsignalled variable delay of reinforcement schedule was the baseline condition relative to an immediate reinforcement schedule.

3.2.2. Experiment 2 - Resistance to response-independent reinforcement produced by delay and nondelay schedules of reinforcement.

Introduction

Experiment 2 differs from experiment 1 in two respects. First, the subjects were transferred to a response-independent reinforcement schedule after exposure to both an immediate and an unsignalled delay of reinforcement schedule. Second, the temporal distribution and rate of response-independent reinforcement were matched to the obtained rate and temporal distribution of reinforcement prevailing during the prior baseline phase.

Method

Subjects

Two male rats, 1 Sprague-Dawley hooded and the other Long-Evans hooded, which were about 9 months of age at the beginning of the experiment served as subjects. They were maintained at 80% of their free feeding weights. They were individually housed and ad lib water was available in their home cages. They had previous experience of continuous reinforcement, variable delay of reinforcement, VR and VT schedules.

Apparatus

The same as in experiment 1.

Procedure

Since both of the subjects had previous operant conditioning experience, they were introduced to the sequence of schedules shown in Table 3.2. The delay of reinforcement schedule was programmed in exactly the same way as in experiment 1. The parameters were T = 5sec, p = 0.2. The immediate reinforcement schedule was programmed in an identical manner except that the output of the probability generator 'set-up' a reinforcer which was delivered after the rat emitted a further response. The parameters were the same as those used for the delay of reinforcement schedule. Notice that, whereas the delayed reinforcement schedule only required 1 response per reinforcer, the immediate reinforcement schedule required 2 responses per reinforcer. (These requirements are of course minima). The nearest

equivalent schedules in the Ferster and Skinner (1957) scheme are tand FR1 VT25sec and tand FR1 VI25sec for the delayed and nondelayed schedules respectively.

To produce the VT schedule, the IRIs occurring during the last 3 sessions of the response-dependent reinforcement phase were recorded. A VT tape for each rat was then prepared which used these values.

This involved representing each IRI value according to its frequency of occurrence during the 3 recorded sessions. The rats were run for 5 days per week during the first condition and daily thereafter. Session duration was 40 minutes.

Table 3.2.

Schedule Order for Experiment 2. The number of sessions given in each condition is shown in brackets.

Order	Rat 1	Rat 4
1	Delay (21)	Delay (21)
2	VT (16)	VT (15)
3	Non-delay (20)	Non-delay (21)
4	VT (15)	VT (15)
5	Non-delay (14)	Non-delay (14)
6	Delay (30)	Delay (30)
7	VT (15)	VT (15)
8	Delay (10)	Delay (10)

Results

Response rates during the last 5 sessions of each condition are shown in figure 3.2. Generally, rate of responding was highest during the non-delay condition, while that observed during response-independent reinforcement was either at an equivalent level to, or even higher than that obtaining under the delay schedule. The sole exception was Rat 4 during the final VT phase. The rat was exposed to two apparatus failures during this condition, however, receiving on one day an abnormally large number of food pellets and on another 25 min of extinction. In 3 out of 4 cases, no response decrement during VT after exposure to the delay schedule was evident; VT after the nondelay schedule was correlated with a substantial decrement in responding.

Postreinforcement pause durations were measured during all conditions. The median value from the last 3 sessions of each condition were as follows: Rat 1 - First exposure to delayed reinforcement - 3.3.sec; second exposure to delayed reinforcement - 4.2sec; First exposure to the nondelay schedule - 2.5sec; and exposure to the final VT condition - 3.3sec: The values for Rat 4 were as follows: 2.0sec; 1.7sec; 1.9sec; and 1.7sec. IRIs without a response were excluded from the calculations involving the VT sessions. It is noticeable that all of the medians were below the minimum IRI value. Further, there is little difference between the delay and nondelay conditions. This contrasts with other reports (e.g., Azzi, Fix, Keller and Rocha e

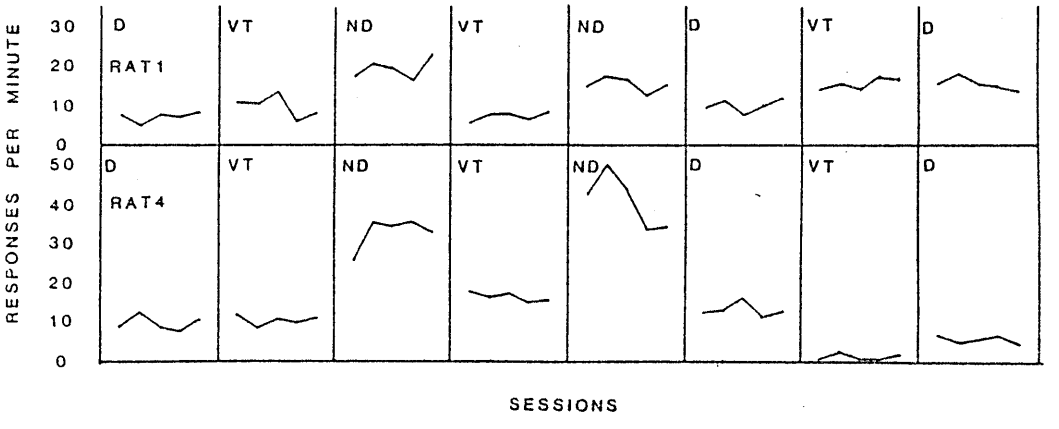


Fig. 3.2. Response rates from the last 5 sessions of each schedule condition. The order of schedule conditions runs from left to right. D = Delay; ND = Nondelay; VT = Variable-time.

Silva, 1964; Morgan, 1972) in which longer PRPs were associated with a delayed reinforcement schedule relative to an immediate reinforcement schedule.

Mean delays from the last response to the delivery of reinforcement were measured during 4 consecutive sessions of the second exposure to the delay schedule. These were: Rat 1 - 5.03sec (range 0 - 67sec); Rat 4 - 10.9sec (range 0 - 117.5sec). The ranges are in excess of those published by other authors, e.g., Sizemore and Lattal (1977) and Williams (1976).

Discussion

The results provide strong support for the position advanced by Schoenfeld et al (1973). Allowing both R and ~~R~~ to be contiguous with the reinforcer during the response-dependent reinforcement condition leads to unusually strong resistance to the response decrementing properties of response-independent reinforcement. Following an immediate reinforcement condition with a VT schedule is correlated with a substantial decline in response rate.

The results conflict with correlation theory. This theory would have to argue that the lack of a response decrement under a VT schedule after training under a variable delay of reinforcement was due to a lack of discrimination between the contingencies (e.g., Rachlin, 1978). There was evidence, however, for response rate enhancement during VT relative to a prior baseline response-dependent condition

(Rat 1, VT after delay). This differential in rate of responding, according to correlation theory, indicates that the rat did in fact discriminate between the two conditions. Rate enhancement effects during VT are the most difficult kind of result for molar correlation theory to explain. They do occur in the literature (e.g., Lattal and Boyer, 1980; Lattal and Bryan, 1976).

There were no cases of complete response elimination under the VT condition. One reason for this could be the type of discriminative control which the reinforcer developed (Rescorla and Skucy, 1969). The PRP data indicate that the reinforcer set the occasion for responding. Given that all of the median PRPs were shorter than the minimum IRI, it is likely that a pattern of behaviour emerged such that there would be at least one R-occurrence between reinforcers. This variable, however, cannot provide a full account of the data because resistance to the VT schedule was better after the delay schedule than after the nondelay schedule despite the fact that the median PRP was shorter in the latter case.

The variable which appears to be of most importance in determining resistance to the VT schedule is the presence of a variable delay of reinforcement during the baseline condition. This sort of schedule is likely to lead to similar distributions of response-reinforcer contiguities as those that obtain during a VT condition as long as the rate and temporal distribution of reinforcers is matched across the response-dependent and response-independent

reinforcement phases.

Conclusion

1. It is possible to obtain no decrement in response rate during a VT condition relative to a prior condition in which responding was maintained by a response-dependent reinforcement schedule. This is more likely to occur after exposure to a delayed reinforcement schedule than to an immediate reinforcement schedule (Schoenfeld et al, 1973).

2. Rate of response-independent reinforcement is related to response rate. Where there is a discrepancy in reinforcement rates between the response-dependent and response-independent reinforcement conditions such that reinforcement rate is higher in the latter case, response decrement may occur (Experiment 1; Sizemore and Lattal, 1977), although the effect may be parameter dependent (see Lachter et al, 1971).

3. Temporal distribution of reinforcement across response-dependent and response-independent reinforcement conditions is related to resistance to response-independent reinforcement. Specifically, if the minimum IRI during the VT phase is less than that in a prior condition, a rapid decline in response rate is likely to occur (Experiment 1; Lattal and Boyer, 1980; Lattal and Bryan, 1976; Zeiler, 1977b, 1979b). This result provides some confirmation for the explanation given to account for the response decrement during VT observed by both Catania and Keller (1981) and Sizemore and Lattal (1977) proposed in section 2.6.1.1.

These pilot experiments lead to a number of important procedural considerations. Since the rate and temporal distribution of reinforcement may influence resistance to response-independent reinforcement, and since we are concerned with examining the effects of removing a dependency between responding and reinforcement, it would seem advisable to hold these two variables constant across the response-dependent and response-independent reinforcement conditions. In all of the experiments to be reported, both rate and temporal distribution of reinforcement were held constant across the transition from response-dependent to response-independent reinforcement. The rationale for each experiment is presented in the appropriate chapter.

CHAPTER 4 EXPERIMENT I: THE EFFECTS OF VARYING RATE OF RESPONDING DURING RESPONSE-DEPENDENT REINFORCEMENT UPON RESPONSE MAINTENANCE UNDER VT SCHEDULES. RATIO VERSUS INTERVAL SCHEDULES.

4.1. Introduction

The most important result emerging from the pilot experiments was that a response initially trained and maintained under a response-dependent reinforcement schedule could be left relatively unaffected when the dependency between responding and reinforcement was subsequently removed. This was most likely to occur when the baseline response-dependent schedule permitted contiguities between both response and other behaviour with reinforcement.

It is possible that the imposition of an unsignalled variable delay of reinforcement is not the only procedure which produces resistance to response-independent reinforcement. Lattal (1972), Schoenfeld et al (1973) and Schoenfeld and Farmer (1970) have all suggested that schedules which are associated with high rates of responding are likely to be associated with stronger resistance to the response-decrementing effects of response-independent reinforcement relative to response-dependent reinforcement schedules which induce low rates. The reason for this is that in the former case, emissions of R are likely to dominate the behaviour stream therefore increasing the likelihood that free reinforcers will contact them. In the case of schedules which induce low rates, emissions of other

behaviour may dominate the behaviour stream and examples of these will be more likely to be contacted by the reinforcer during the response-independent reinforcement phase. Thus, competition between responding and 'not responding' will be more severe in the latter case relative to the former. Since ratio schedules are associated with higher rates of responding relative to yoked interval schedules (Catania, Mathews, Silverman and Yohalem, 1977), the former should be correlated with stronger resistance to response-independent reinforcement relative to the latter schedules. To the extent that response rate prevailing during the baseline is the primary controlling variable of resistance to response-independent reinforcement, a similar prediction would hold when variable delays of reinforcement are added to ratio and yoked interval schedules.

In the following experiment, rats are exposed to both ratio and interval schedules which were either delayed or immediate before being presented with VT schedules.

4.2. Method

Subjects

Four experimentally naive male hooded (Sprague-Dawley) rats, about 6 months of age at the beginning of the experiment, were maintained at 85% of their free-feeding weights. They were individually housed and ad lib water was available in home cages.

Apparatus

Four identical two-lever Campden Instruments rodent test chambers (Model 410) with internal dimensions of 24.5 x 23 x 20.5 cm were used. The chambers were housed inside sound-attenuating chests which also provided masking noise from a ventilating fan. Both levers were removed and the left lever was replaced by a Campden Instruments retractable lever (Model 446) which was situated 6.4 cm from the floor of the cage (to the top of the lever), 3 cm from the food trough and protruding 1.7 cm into the cage. A houselight situated in the ceiling of the chamber was continuously illuminated during all experimental conditions. Reinforcement consisted of the delivery of 45-mg Campden Instruments food pellets. All experimental events were controlled by conventional logic equipment located in another room.

Procedure

After the lever press response had been shaped the rats were divided into two pairs in which one rat was a "master" rat while the other was yoked to it. The "master" rats were exposed to an ascending series of VR schedules (from VR3 to VR20) over the next eight sessions. During these sessions a reinforcer delivered to the "master" rat "set up" a reinforcer which was dispensed to the yoked animal after it had emitted a further response (yoked VI). From the ninth session onwards the experimental schedules became operative. One pair of rats was designated the immediate reinforcement group (Rats 1 and 2) while the other was designated the

delayed reinforcement group (Rats 3 and 4).

Immediate reinforcement group

The VR schedule was programmed by inputting the "master" rat's lever presses to a probability randomizer set (initially) at 0.04. After 33 sessions with this parameter the percentage of outputs was reduced to 0.02. This yielded a VR50 schedule. Output from the probability randomizer "set up" a reinforcer for the yoked VI rat. This reinforcer was delivered after the next response. Each rat served as both "master" and yoked partner during the experiment. The sequence of schedules and number of sessions each schedule was in effect are shown in Table 4.2.

Delayed reinforcement group

Responses from the "master" rat were input to a probability randomizer set at 0.07. Completion of the VR component allowed access to a VT schedule which was programmed as follows. Output from a recycling timer set at 5 sec was fed to a probability randomizer. Output from the probability randomizer delivered the reinforcer, and once more required satisfaction of the VR component. The initial setting on the probability randomizer was 0.8; this was reduced to 0.4 for 16 sessions. Finally it was reduced still further to 0.2, providing a tandem VR14 VT25 s schedule. This schedule is designated VR-delay. The yoked VI-delay animal was yoked only in so far as the VI component was concerned. That is, each time the "master" rat satisfied the VR component access to an independent VT schedule (same parameters as above) was

"set up". Access was gained by the emission of the next response from the yoked rat. This schedule is a tandem VI VT schedule, designated here as VI-delay. Each rat performed as both "master" and yoked partner during the experiment. The sequence of schedules and number of sessions each schedule was in effect are shown in Table 4.2. To produce the response-independent VT schedule the inter-reinforcement intervals occurring during the last five sessions of the condition preceding each response-independent reinforcement phase were recorded and a VT tape was prepared using these values. Session duration was 30 min. The rats were run on five days per week during the first three conditions and 6 days per week thereafter.

There was a 6-day break during the first condition for the immediate reinforcement group. This was occasioned by an apparatus malfunction. There were an additional 36 sessions, however, before the transition to response-independent reinforcement was made. Before exposure to the last three conditions, the delayed reinforcement group was exposed to 10 sessions in which the delay parameter was gradually increased from 0 sec to 25 sec in order to boost response rates.

TABLE 4.2.

Schedule order for Experiment 1. The number of sessions given in each condition is shown in brackets.

Immediate reinforcement group			Delayed reinforcement group	
Order	Rat 1	Rat 2	Rat 3	Rat 4
1	VR	VI (51)	VR-delay	VI-delay (47)
2	VT	VT (20)	VT	VT (20)
3	VR	VI (20)	VR-delay	VI-delay (29)
4	VI	VR (40)	VI-delay	VR-delay (46)
5	VT	VT (20)	VT	VT (20)
6	VI	VR (22)	VI-delay	VR-delay (21)

4.3. Results

Response per minute during the last 6 sessions of each schedule condition are shown in figure 4.1. Rates of responding were highest during the ratio conditions for both the immediate and delayed reinforcement groups (Catania et al, 1977; Catania and Keller, 1981). It is clear that the VT schedule after both of the immediate reinforcement schedules was associated with a substantial decrement in responding. Rat 2's VT-after-VR data are confounded by an apparatus malfunction. This took place on session 5 of VT after VR and took the form of the pellet dispenser remaining open. Response rate never recovered to pre-session 5 levels. There was no evidence of response decrement during VT after exposure to the delay schedule. In fact, there is

one case of response rate enhancement, i.e., rate of responding was higher during the VT schedule relative to both baseline determinations. These trends are confirmed by statistical analysis. The rate of responding during each VT session was compared with the mean rate of responding obtaining during the final 6 sessions of the previous baseline phase by use of the Sign Test (Siegel, 1956). The results of this comparison are shown in Table 4.2. This shows that the immediate reinforcement schedules were associated with response decrement during the VT condition, while there was either no difference in response rate between the response-dependent and response-independent phases or rate was significantly higher in the latter phase after exposure to the delay schedule.

TABLE 4.2.

Level of significance between response-dependent and VT reinforcement phases.

	Rat 1	Rat 2	Rat 3	Rat 4
After Ratio	.001[c]	.001[c]	n.s.	n.s.
After Interval	.001[c]	.001[c]	n.s.	.001[d]

[c]Significant response decrement during vT

[d]Significant response during VT

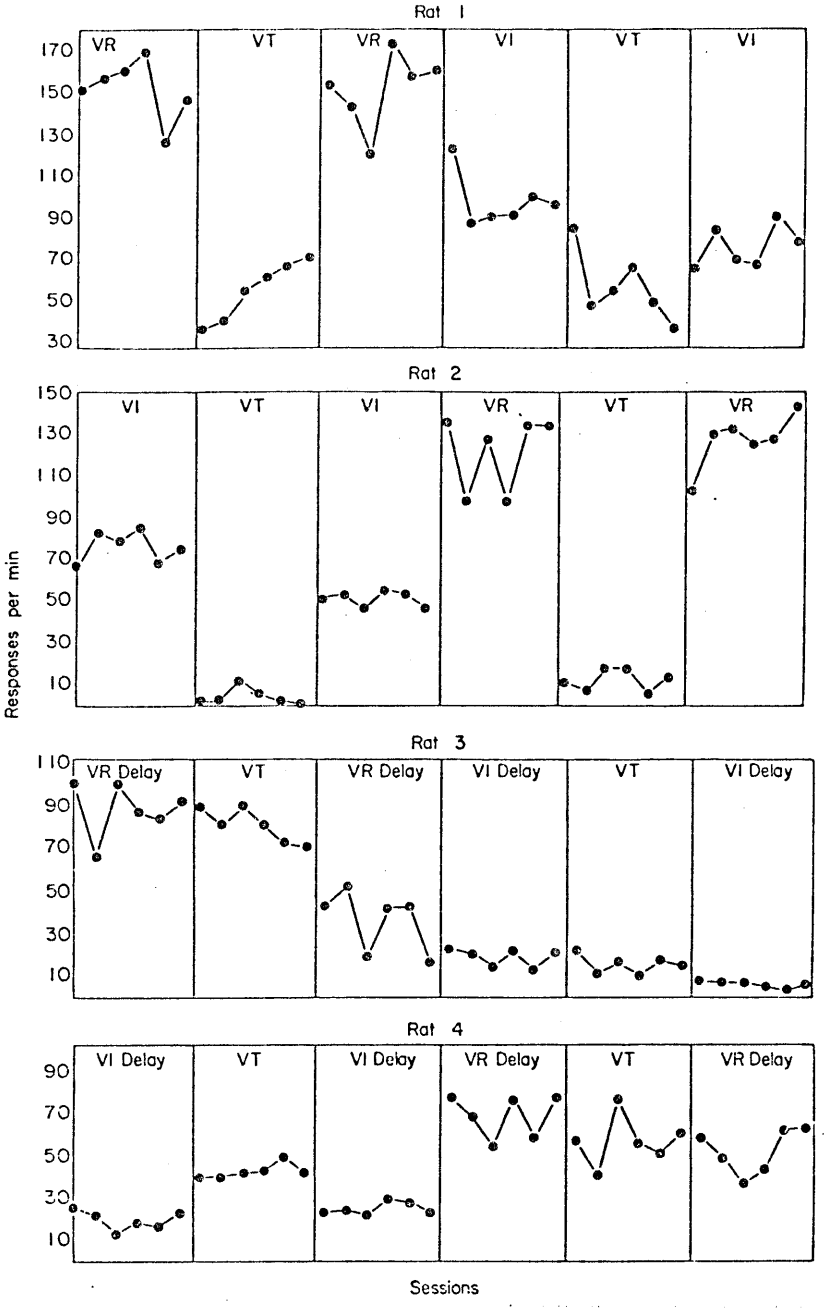


Fig. 4.1. Response rates from the last 6 sessions of each schedule condition. VR = variable-ratio; VI = variable-interval; VR Delay = variable-ratio delay schedule; VI Delay = variable-interval delay schedule; VT = variable-time.

The trends shown in both fig 4.1 and Table 4.2 are made somewhat clearer in figure 4.2. In that figure, response rate during each VT session was normalized with respect to the mean rate of responding during the final 6 sessions of the prior response-dependent reinforcement phase. A normalized rate of less than 1 indicates response decrement, while a rate in excess of 1 indicates response rate enhancement. It is clear from fig 4.2 that there was a cyclical trend of uneven periodicity in normalized rate of responding (Williams, 1976). This is the case for both immediate and delayed reinforcement baseline conditions.

In order to assess the effects of rate of responding during baseline upon subsequent resistance to response-independent reinforcement, each rat's normalized rate after the ratio condition was compared with the normalized rate after interval condition. The comparison was assessed by use of the Wilcoxon matched-pairs signed ranks test (Siegel, 1956). For Rat 1 the VI schedule led to significantly greater resistance to response-independent reinforcement than did the VR ($T=17.5$, $p<.005$). A similar result held for Rat 4 ($T=3$, $p<.005$). No significant difference emerged between the conditions for both Rats 2 and 3 ($T=77$, $p>.05$, $T=108$, $p>.05$ respectively). Thus the schedules which induced the lower rates of responding tended to produce the greater resistance to response-independent reinforcement. It has to be noted, however, that Rat 2's data were somewhat affected by the apparatus malfunction (see fig. 4.2). Further, rates of reinforcement varied across conditions for all of the

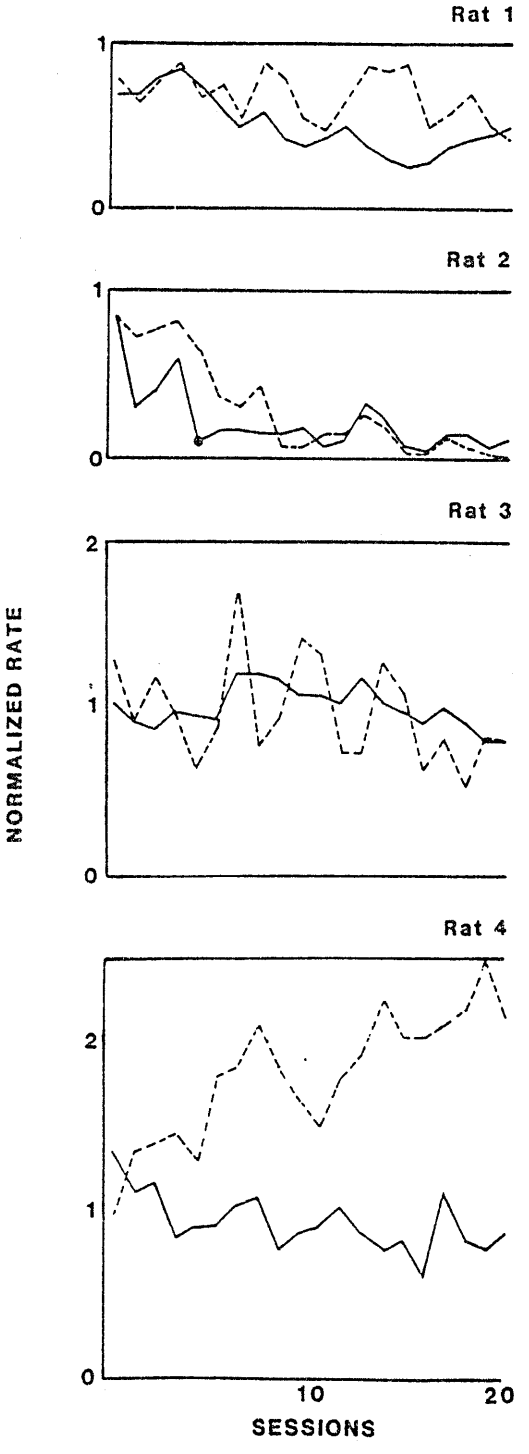


Fig. 4.2.

Normalized rate of responding during the VT sessions. Solid line indicates VT after the ratio schedule; dashed line indicates VT after the interval schedule. The point marked with a solid circle for Rat 2 indicates the session in which there was an apparatus malfunction - see text for details.

rats and this may have affected the result, although no systematic trend appears in the data.

The change in the percentage of IRIs without a response over sessions is shown in figure 4.3. The logic underlying this index of behaviour is that as response decrement begins to occur so the number of IRIs without a response will increase (Catania and Keller, 1981). There is a direct relation between the percent of IRIs without a response and sessions of VT for the immediate reinforcement group (with the possible exception of Rat 1 after VI). No clear relation emerged for the delayed reinforcement group. This is probably due to the relatively small number of IRIs without a response which occurred for this group. The degree of association between the percent of IRIs without a response and response rate during each VT session was assessed by Spearman Rank Difference correlations (Guilford, 1956). These are presented in Table 4.3.

Table 4.3

Rank difference correlations between response rate and percent of IRIs without a response during VT.

	Immediate Reinforcement		Delayed Reinforcement	
After Ratio	-0.88[1]	-0.96[1]	0.07[2]	-0.33[2]
After Interval	-0.87[1]	-0.74[1]	-0.88[1]	-0.37[2]

[1] Significant at the 1% level

[2] Not statistically significant

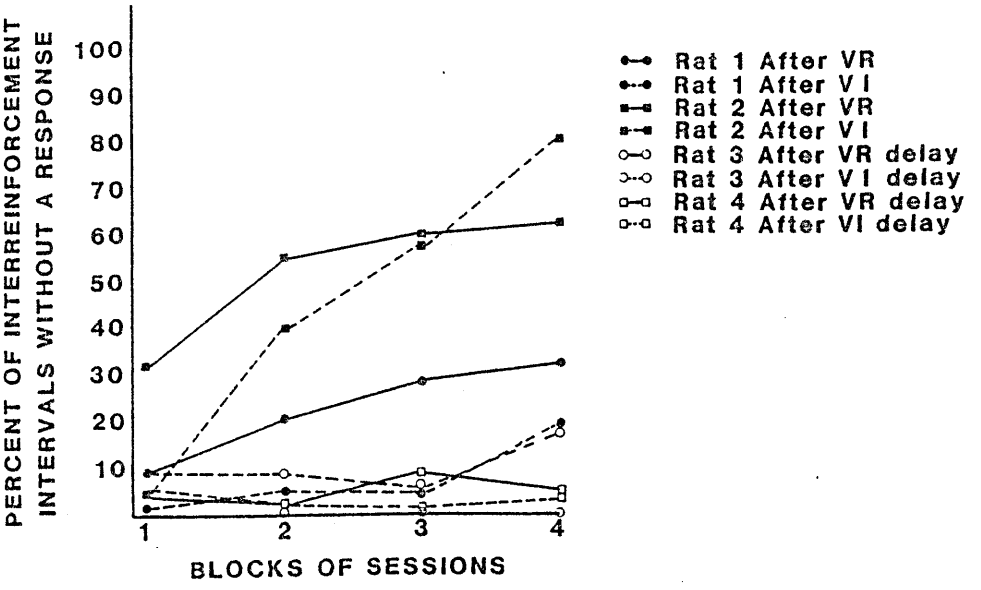


Fig. 4.3. Percent of IRIs without a response as a function of blocks of sessions. Points are the means from 5 sessions.

The correlations for the immediate reinforcement group are all highly significant, while those for the delayed reinforcement group generally fail to reach an acceptable level of significance. The results from the delayed reinforcement group could be due to the relatively few occurrences of IRIs without a response, e.g., Rat 3 lever pressed at least once in 1039 of 1042 IRIs during VT after the VR-delay condition (the equivalent frequencies for VT after VI-delay for this rat were 713 out 801). Where IRIs without a response begin to occur at a reasonably high frequency, then there is a strong relationship between this variable and response rate. Representative cumulative records from each phase for all rats are shown in figures 4.4a-d. The patterns generated under the VR and VI schedules were typical (Ferster and Skinner, 1957). Under the VR schedule, responding occurred soon after reinforcement, and there were cases of a local increase in response rates. Occasional episodes of pausing did emerge, but these were confined to the middle of an IRI. Responding under the VI schedule was somewhat uneven. There were examples of both local positive and local negative acceleration. Responding under the VT conditions can be best described as prolonged pausing intermingled with patterns resembling those observed during the prior response-dependent phase. IRIs without a response were more likely to occur at the end of a session where rate of responding declined dramatically. The delay schedules induced quite different patterns of responding from those seen under the immediate reinforcement schedules. The VI-

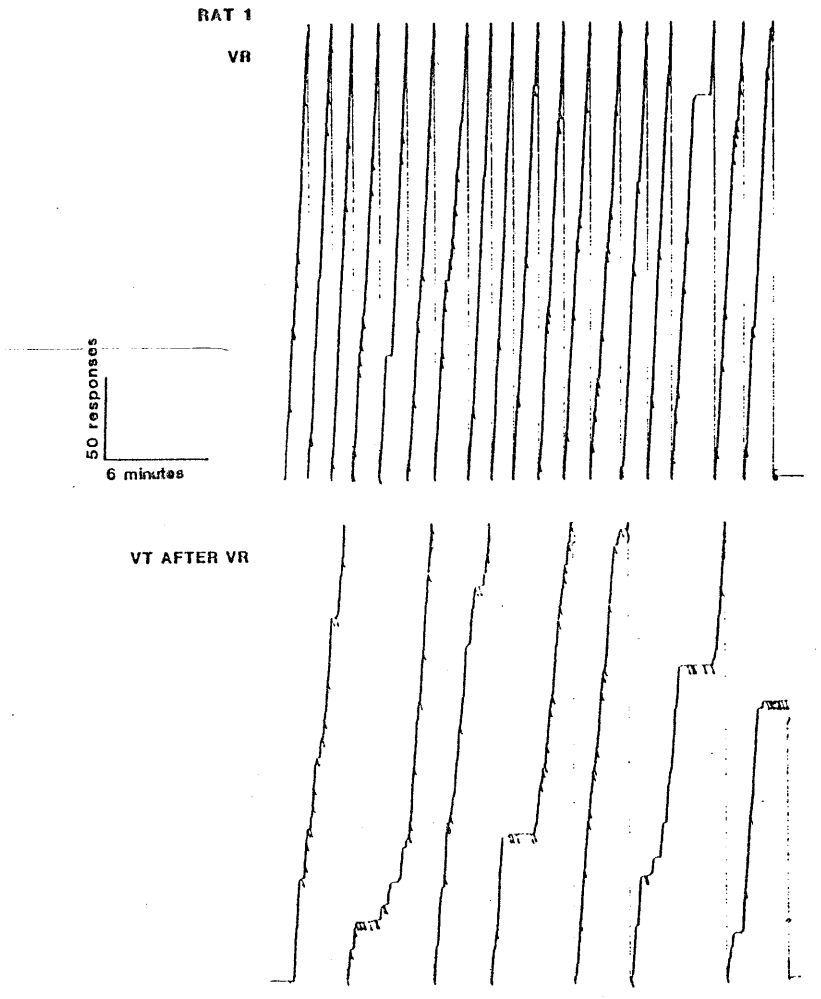
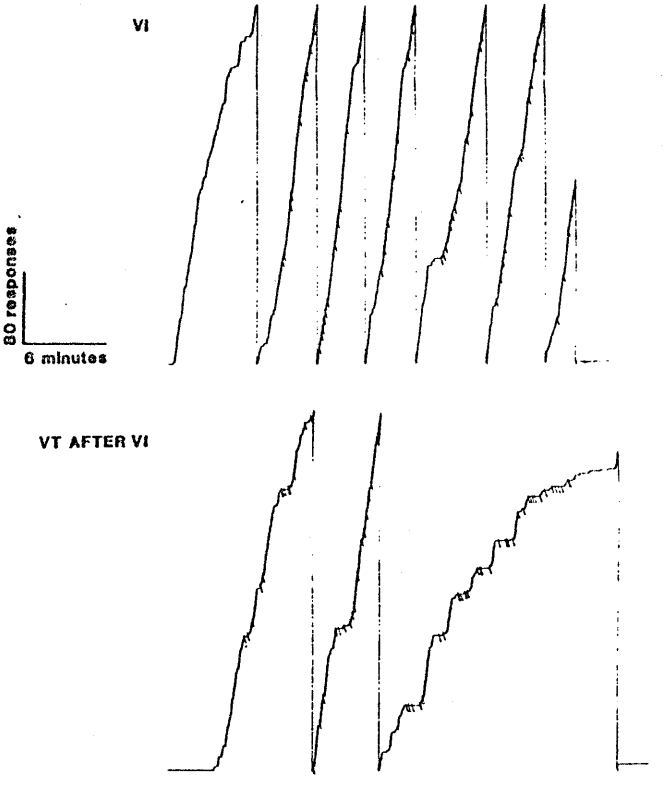


Fig. 4.4a

Cumulative records from each schedule condition for Rat 1.



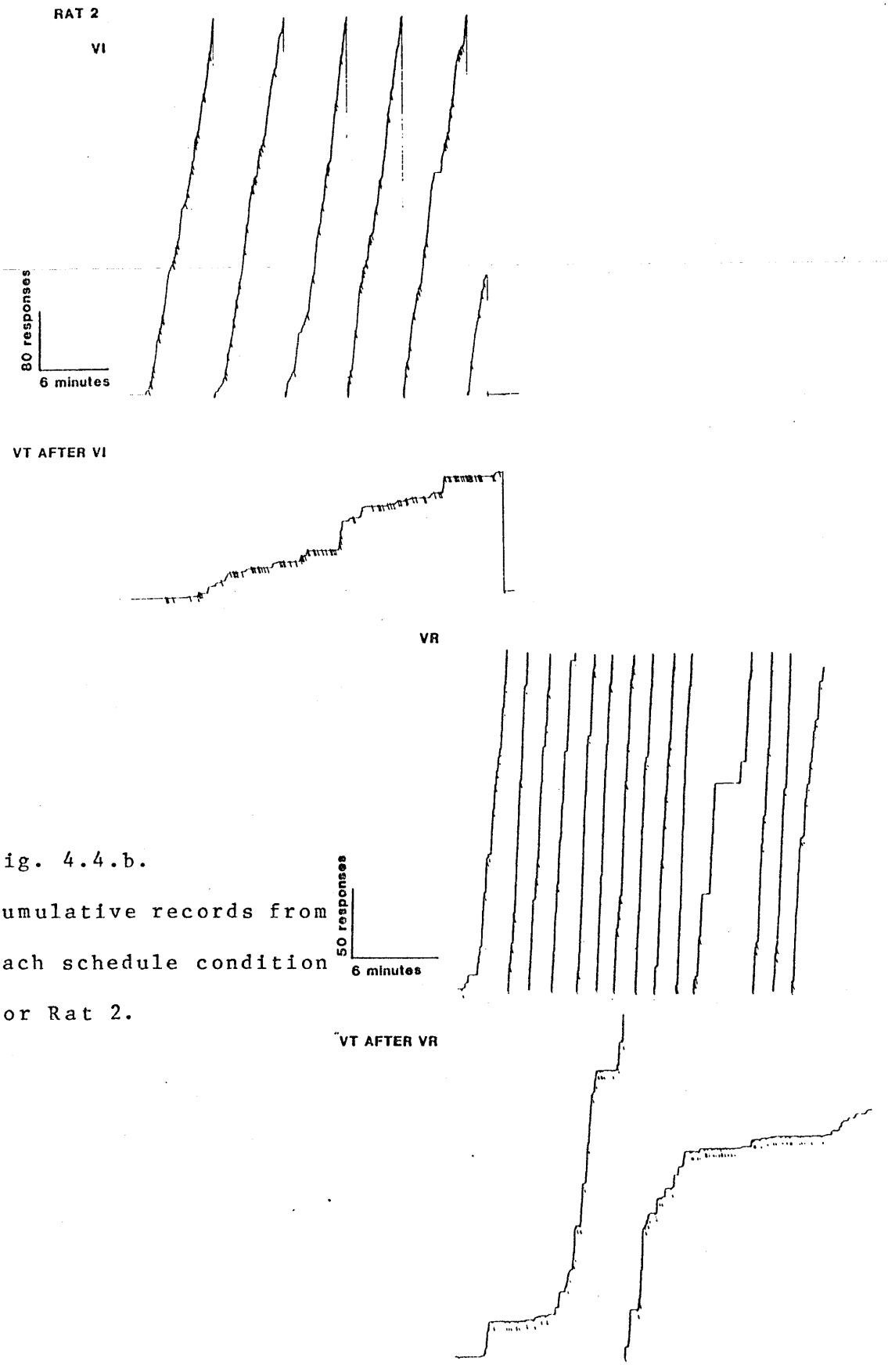
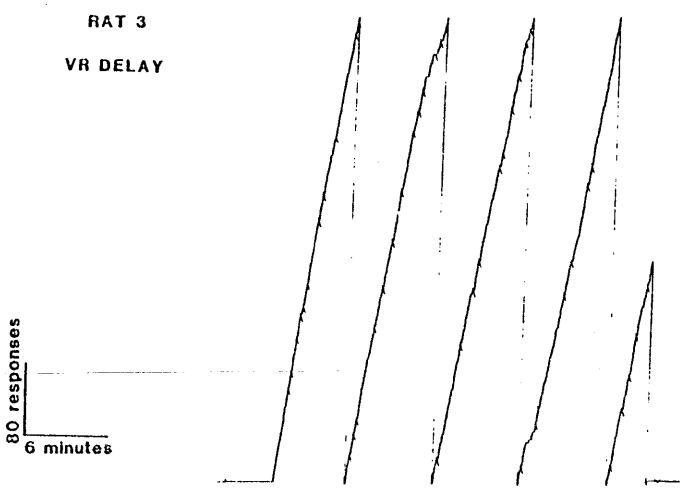
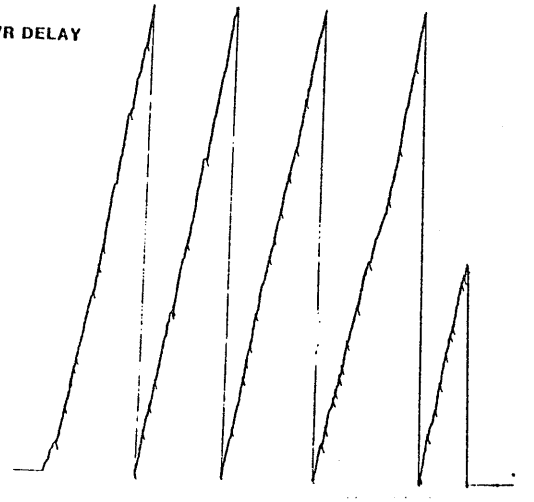
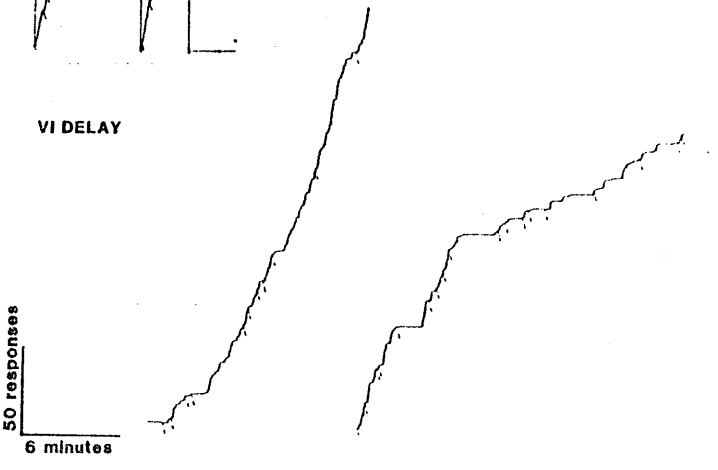


Fig. 4.4.b.
Cumulative records from each schedule condition for Rat 2.







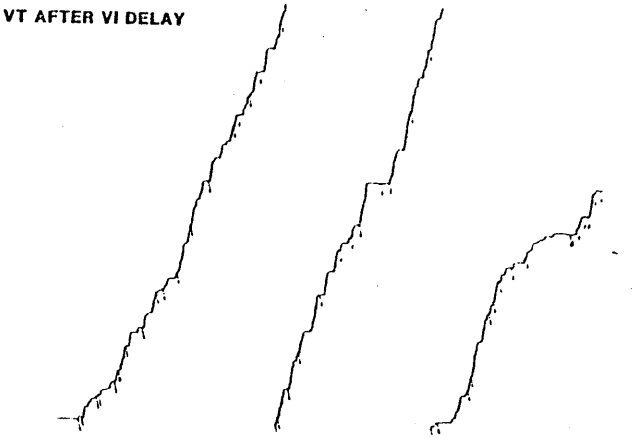
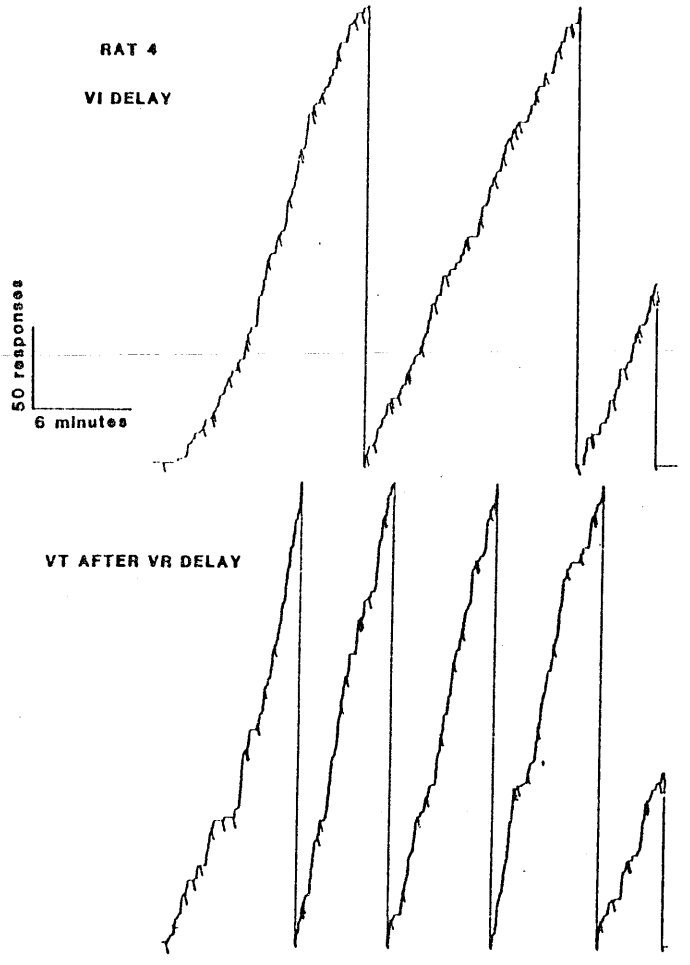


Fig. 4.4c.
Cumulative records from each schedule condition for Rat 3.



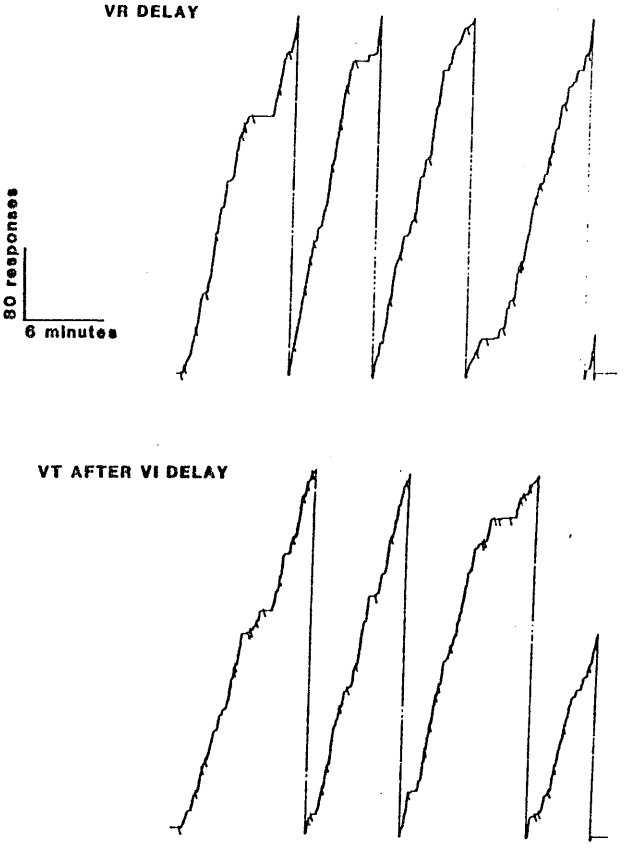


Fig. 4.4d.
Cumulative records from each schedule condition for Rat 4.

delay schedule tended to induce a much more even cumulative record. The patterns of responding associated with the VT schedules resembled those observed during the prior response-dependent condition (Lattal, 1972).

4.4. Discussion

Two major results emerged from this study. First, rate of responding during the baseline schedule was not positively related to subsequent resistance to response-independent reinforcement. Second, resistance to response-independent reinforcement was stronger after delayed reinforcement than after immediate reinforcement.

The first result conflicts with the view proposed by Schoenfeld and Farmer (1970) and Schoenfeld et al (1973) that schedules which induce high rates of responding will produce stronger resistance to response-independent reinforcement. It could be the case, however, that where the rate and temporal distribution of reinforcers is matched across the response-dependent and response-independent phases, rate of responding assumes less importance than it otherwise would. The data on superimposing free reinforcers onto a baseline maintained by response-dependent reinforcement are instructive here. Those data reveal that response rate increment is just as likely to occur on a baseline maintained by an interval schedule (lower rate) as it is when the baseline schedule is a ratio one (higher rate) (Lattal and Boyer, 1980; Lattal and Bryan, 1976; Zeiler, 1979b). Where the prevailing response rate - and

hence schedule type - may acquire controlling properties is where the rate of response-independent reinforcement varies from that during the baseline. For example, where response-independent reinforcement occurs more frequently than had obtained during the baseline and the organism allocates more time to emitting behaviours other than the designated operant, response decrement during VT would be more likely to occur (e.g., Sizemore and Lattal, 1977). In those cases where the organism allocates more time to emitting the response then the extra reinforcers may well be correlated with a response rate enhancement (Lachter, 1971; Lachter et al, 1971). Although it is possible to propose such arguments, the response rate data do not confirm expectations from contiguity theory.

On the other hand, the comparison between the effects of allowing both the designated operant and other behaviour to be contiguous with a reinforcer with a schedule which only permitted response-reinforcer contiguities provides strong support for the view proposed by Schoenfeld et al (1973). These results confirm those found in the second pilot experiment. The results once more conflict with expectations from molar correlation theory (Baum, 1973). Although this theory can explain the response decrements observed and possibly even the cases where no decrement in response rate was noted, it cannot explain either the response rate increment observed for Rat 4 after VI-delay or the cyclities in the VT data (Williams, 1976). Finally, it seems strange that although both of the rats in the delay

condition could discriminate the ratio-based schedule from the interval-based one (on the basis of observed response rates) they were unable to detect a difference between these conditions from one in which there was no programmed correlation between their behaviour and reinforcement.
Although the results can be best explained by the contiguity view, that position is also faced with some difficulties. For example, if VT schedules are merely variants of a delay of reinforcement schedules, then responding under the VT schedule should persist indefinitely. Data from this experiment do show persistent responding under VT conditions after exposure to various kinds of immediate reinforcement schedule, as do data from other studies (Lattal, 1972, 1973; Rescorla and Skucy, 1969; Sizemore and Lattal, 1977) but elimination of responding from the behaviour stream is also often found (Boakes, 1973; Halliday and Boakes, 1972; Lachter, 1971; Lachter et al, 1971). Although the view espoused by Schoenfeld et al (1973) can account for response elimination in specific cases (e.g., their experiment 3), the boundary conditions of response maintenance under response-independent reinforcement cannot be specified.

Nevertheless, it seems that allowing both the designated operant and other behaviour to be contiguous with the reinforcer during the baseline is a potent variable in producing resistance to the response-decrementing effects of response-independent reinforcement.

CHAPTER 5 EXPERIMENT II: TRANSFER FROM IMMEDIATE AND DELAYED FIXED-RATIO SCHEDULES TO VT SCHEDULES

5.1. Introduction

This experiment differs from the last one in that FR schedules are substituted for the VR schedules. In addition, a between-subjects design is used. One of the major differences between FR and VR schedules is the pattern of behaviour which they induce (Ferster and Skinner, 1957). Typically, FR schedules are associated with a break-run pattern, whereas the VR schedule characteristically induces a constant high rate pattern of responding. Whereas the PRP duration is related to the ratio value in the FR schedule, no such relation holds for the VR schedule (Ferster and Skinner, 1957). An alternative way of stating these relationships is to note that the reinforcer develops different discriminative properties on these two schedules, such that the reinforcer on a FR schedule sets the occasion for no-responding. To the extent that the discriminative properties of the reinforcer are one of the important controlling variables in producing resistance to response-independent reinforcement, it might be expected that a VR schedule would produce stronger resistance to the response-decrementing effects of response-independent reinforcement relative to a FR schedule. There is evidence to suggest, however, that FR schedules induce very persistent patterns of responding, even across response systems and experimental conditions (Alleman and Zeiler, 1974; Eisenberger, Carlson and Frank, 1979; Eisenberger, Terborg and Carlson, 1979; Wong and Amsel, 1976). Response persistence is directly

related to the FR value during the baseline (Wong and Amsel, 1976). It could be argued, therefore, that a FR schedule will produce unusually strong resistance to response-independent reinforcement.

In the following experiment rats were exposed to either a FR schedule or a FR+delay schedule before being transferred to a matched VT schedule. This experiment was carried out twice because the results conflicted with those of the previous experiments. In one procedure a yoked interval condition was also operative, this was not used in the replication, however, because more data were sought from the FR-based schedules. Based on the results from the experiments already reported, it would be expected that response persistence would be strongest after the delay of reinforcement schedules. In addition, response decrement should be very slow after the immediate FR schedule (Alleman and Zeiler, 1974; Edwards et al, 1970).

5.2. Method

Subjects

Seven experimentally naive male hooded rats, 3 of which were of the Lister breed and 4 were Sprague-Dawley, were about 3 months of age at the beginning of the experiment. They were maintained at 85% of their free feeding weights. They were individually housed and had ad-lib water available in their home cages.

Apparatus

Two Campden Instruments rodent test chambers of the same dimensions as were used in Experiment I.

Procedure

The rats were run in 2 squads. Rats 1, 4 and 7 were in the first squad while Rats 2, 3, 5 and 6 were in the second. All of the rats were exposed to the conditioning chamber for one session. During this session the food tray was filled with food pellets. During the next session, the rats were exposed to a conc FR1 VT30sec schedule. If the rats did not press the lever during this session they were shaped to do so by the method of successive approximations. They were then formed into an immediate reinforcement group and a delayed reinforcement group.

Immediate Reinforcement Group - Rats 1, 2 and 3

The rats were exposed to FR schedules in which the ratio parameter was gradually increased to a final value of FR50. For Rat 1, this increase was achieved in 24 sessions, while Rats 2 and 3 had the FR50 introduced after 40 sessions. Following FR50 training the rats were exposed to VT schedules matched in terms of rate and temporal distribution of reinforcement to those prevailing during the last 6 sessions of the prior baseline condition. Following exposure to the VT schedule, the rats were returned to the FR50 condition. The sequence of schedules and the number of sessions each schedule condition was in effect are shown in Table 5.1.

Delayed Reinforcement Group - Rats 4, 5, 6 and 7.

Rats 4 and 7

Rat 4 was initially exposed to a FR schedule the terminal value of which was FR20 (14 sessions). The FR parameter was then reduced to 14 and a VT schedule was added to the FR schedule in a tandem arrangement. The VT schedule was programmed in a manner similar to that employed in Experiment I. In this case, T was set at 5 sec, while p was initially set at 0.8. This was reduced over 5 sessions to 0.3. This value was retained for the remainder of the baseline period. This is equivalent to a tand FR14 VT 16.7sec and is called a FR-delay schedule. Rat 7 was yoked to Rat 4, initially on the immediate FR schedule (yoked VI). The yoking procedure was maintained during the delay schedule, but the yoking arrangement was only operative for the VI component of the tand VI VT. The VT component had the same parameters for Rat 7 as it had for Rat 4. Thus the schedule for Rat 7 was a tand VIx VT16.7sec schedule and is called here a VI-delay schedule. Following baseline training, the rats were exposed to a VT schedule matched for rate and temporal distribution of reinforcement with that obtaining during the final 6 sessions of the prior baseline condition. The rats were then returned to their respective baseline schedules. The sequence of schedules and the number of sessions each schedule condition was in effect are shown in Table 5.1.

Rats 5 and 6

These rats were initially exposed to an ascending series of FR schedules in which the terminal ratio was FR25 (29 sessions). The FR parameter was then reduced to FR14 and a VT schedule added to the FR schedule in a tandem arrangement. The parameters of the VT schedule were T = 5 sec, while p was reduced to 0.2 over 11 sessions. It remained at this value throughout the baseline condition, thus yielding a tand FR14 VT25sec schedule. Following baseline, the rats were transferred to VT schedules matched in terms of rate and temporal distribution of reinforcement to those prevailing during the final 6 sessions of the prior baseline condition. The rats were then returned to the baseline condition. Schedule order and number of sessions in each condition are shown in Table 5.1.

The rats were run on 5 days per week and session duration was 30 minutes.

TABLE 5.1.

Schedule order for Experiment II. (Number of sessions is shown in brackets)

	ORDER		
Rat 1	FR(42)	VT (22)	FR(20)
Rat 2	FR(43)	VT (15)	FR(10)
Rat 3	FR(43)	VT (15)	FR(10)
Rat 4	FR-DELAY(47)	VT (22)	FR-DELAY(20)
Rat 5	FR-DELAY(44)	VT (15)	FR-DELAY(10)
Rat 6	FR-DELAY(44)	VT (15)	FR-DELAY(10)
Rat 7	VI-DELAY(47)	VT (22)	VI-DELAY(10)

5.3. Results

There were a number of apparatus failures during the VT phase. These were as follows. Rat 2 experienced an increase in the rate of reinforcement during sessions 1 and 2 when the tape timer delivered occasional double reinforcers (these were separated by about 1 sec). Rat 3 was exposed to the same kind of apparatus malfunction on VT session 2. The tape timer jammed on VT session 1 for Rat 4 and this rat was withdrawn after 19.17 min. Finally, the data were lost for Rat 1 on VT session 8 because the lever was not connected to the counter.

Responses per minute during the last 6 sessions of each schedule condition are shown in figure 5.1. It is clear that there was a considerable decrement in responding for all rats during the VT schedule relative to the prior

baseline condition. It was more difficult to recover baseline response rates for the delayed reinforcement group relative to the immediate reinforcement group. Response rate was much higher during the FR50 condition relative to the FR-Delay schedules, while the yoked interval delay schedule was correlated with a much lower rate of responding relative to the 'master' animal's rate of responding (Catania et al, 1977). Rate of responding during the VT sessions was closer to that observed during the subsequent response-dependent condition for the rats exposed to the delayed reinforcement schedules relative to the immediate reinforcement group's performance.

These trends are more clearly observed when all sessions of VT are considered. Figure 5.2 shows the normalized rate of responding during each VT session. The rates of responding during each VT session were normalized with respect to the mean rate of responding during the final 6 sessions of the previous baseline condition. A normalized rate of 1 indicates no response rate decrement. The data depicted in figure 5.2 indicates that there was considerable response decrement irrespective of the baseline schedule. There is a wide within group variation. Aside from Rats 3 and 4, the trend in normalized rate appears to be better described as cyclic rather than exponential. The cyclicities observed in the delayed reinforcement group were in fact quite typical of the baseline data for Rats 5, 6 and 7. Such cyclicities are probably inevitable under unsignalled variable delay of reinforcement schedules as programmed here, because of the

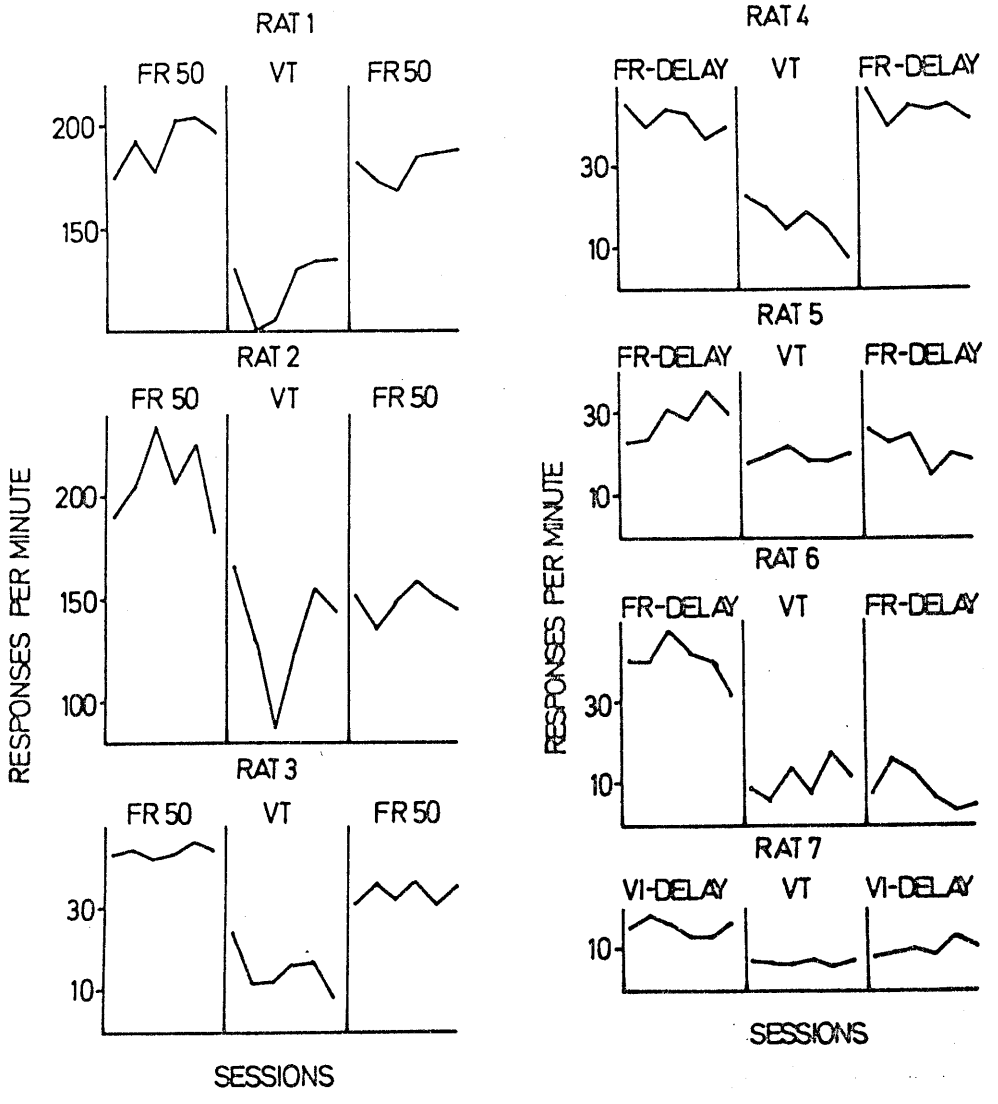


Fig. 5.1. Response rate during the last 6 sessions of each schedule condition.

variation of response-reinforcer contiguities across sessions. The data from the immediate reinforcement group are of interest because in two out of three cases (Rats 1 and 2) they depart markedly from the data observed from the rats undergoing VR and VI schedules in the previous experiment.

The percent of IRIs without a response as a function of blocks of sessions is presented in figure 5.3. In this figure, each block score is based upon the mean percentage from 3 sessions with the following exceptions - Rat 1 blocks 1 and 3 which were based upon 2 sessions; Rats 1, 4 and 7 - block 7 which was based upon 4 sessions. Although the data from the delayed reinforcement group are similar to that shown by the delayed reinforcement group in the previous experiment (with the exception of Rat 6), that from the immediate reinforcement group are markedly different - in fact both Rats 1 and 2 responded during the majority of IRIs. A similar observation can be made with regards to data from Rats 4, 5 and 7, while Rat 6's results are particularly erratic. Spearman Rank Difference correlations were calculated between the proportion of IRIs without a response and response rate during the VT sessions. These were as follows. Rat 1 - -0.54, Rat 2 - -0.60, Rat 3 - -0.61, Rat 4 - -0.57, Rat 5 - -0.04, Rat 6 - -0.86, and Rat 7 - -0.50. All of these correlations are statistically significant with the exception of that for Rat 5. Despite the significance, it can be seen that those for the immediate reinforcement group are of smaller magnitude than

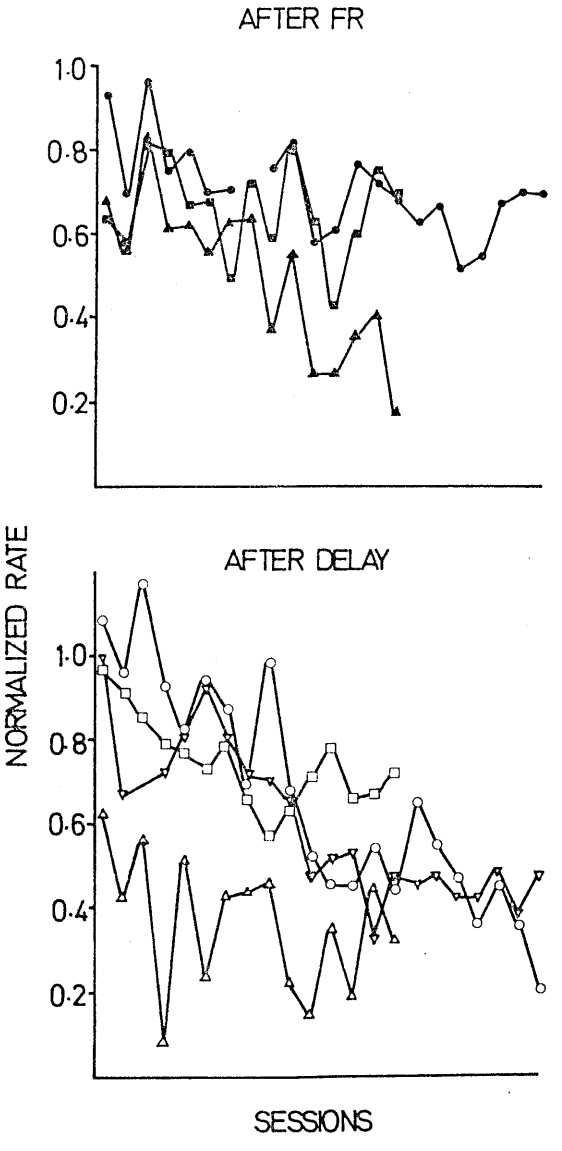


Fig. 5.2.

Normalized response rate during each VT session after exposure to either the FR schedule or the delayed reinforcement schedule. Rat 1-solid circles; Rat 2-solid squares; Rat 3-solid triangles; Rat 4-open circles; Rat 5-open squares; Rat 6-open triangles; Rat 7-open inverted triangles.

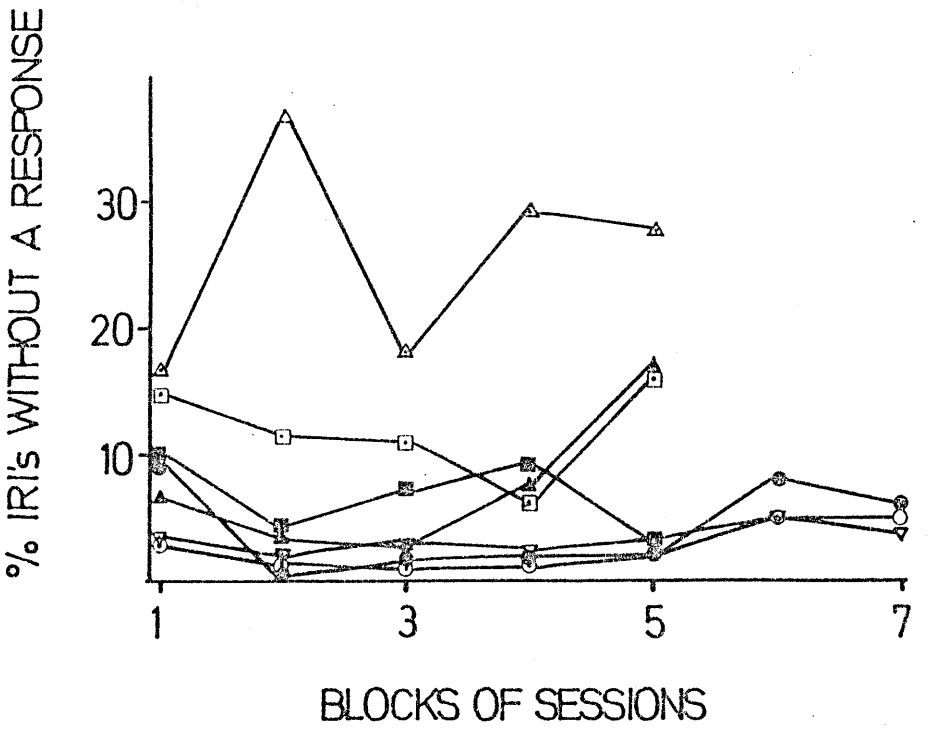


Fig. 5.3. Percent of IRIs as a function of blocks of VT sessions. Key for the individual rats is as in Fig. 5.2.

those found in the previous experiment. Clearly, this variable accounts for less of the variance in response rate during VT after a FR schedule than it does after both a VR and VI schedule. Surprisingly, the opposite effect holds for the delayed reinforcement group, although the correlations are by no means high (with the exception of Rat 6).

Representative cumulative records are presented in figures 5.4a to g. The numbers appended to the VT label signify the respective VT session rather than VT parameter. The pattern of responding induced by the FR schedule can be best described as taking one of two forms. The first is typical break-run pattern usually associated with a FR schedule (Ferster and Skinner, 1957). This sort of pattern is typical of Rat 3's performance. The second pattern, which characterizes Rats 1 and 2's cumulative record is more similar to that usually observed under a VR schedule, i.e., there is a high rate of responding <u>throughout</u> the IRI. It can also be seen that the VT schedule disrupts the former pattern of responding, but has little or no effect upon the latter pattern, with the possible exception of increasing the duration of the PRP. In fact, the VT schedule induces a more typical break-run pattern for Rat 1 than did the FR50 schedule. The patterns of responding associated with the delayed reinforcement schedule can best be described as an uneven form of break-run. In one case there was a rate differential such that rate of responding was higher at the

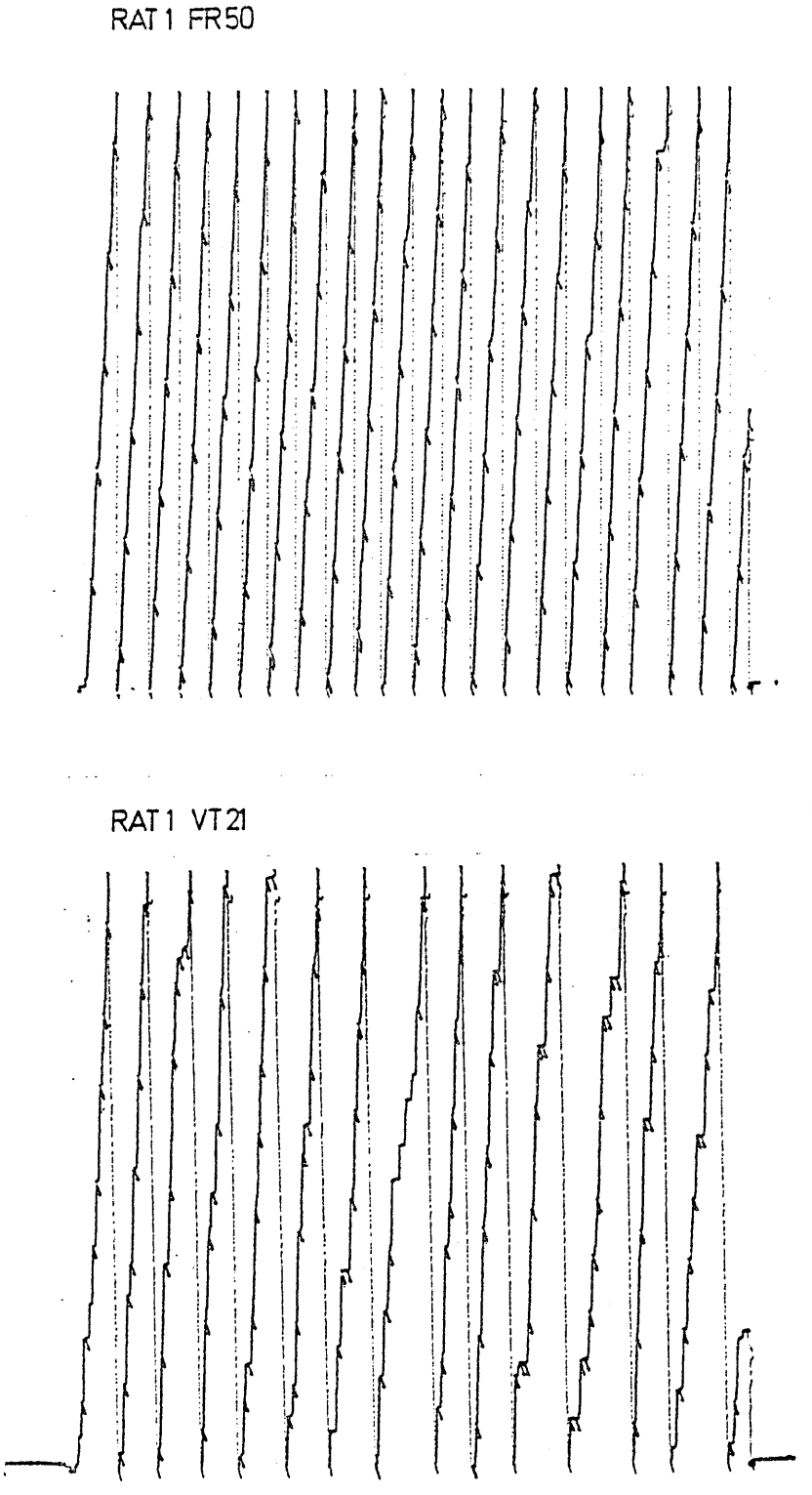


Fig. 5.4a Representative cumulative records for Rat 1 in Experiment II.

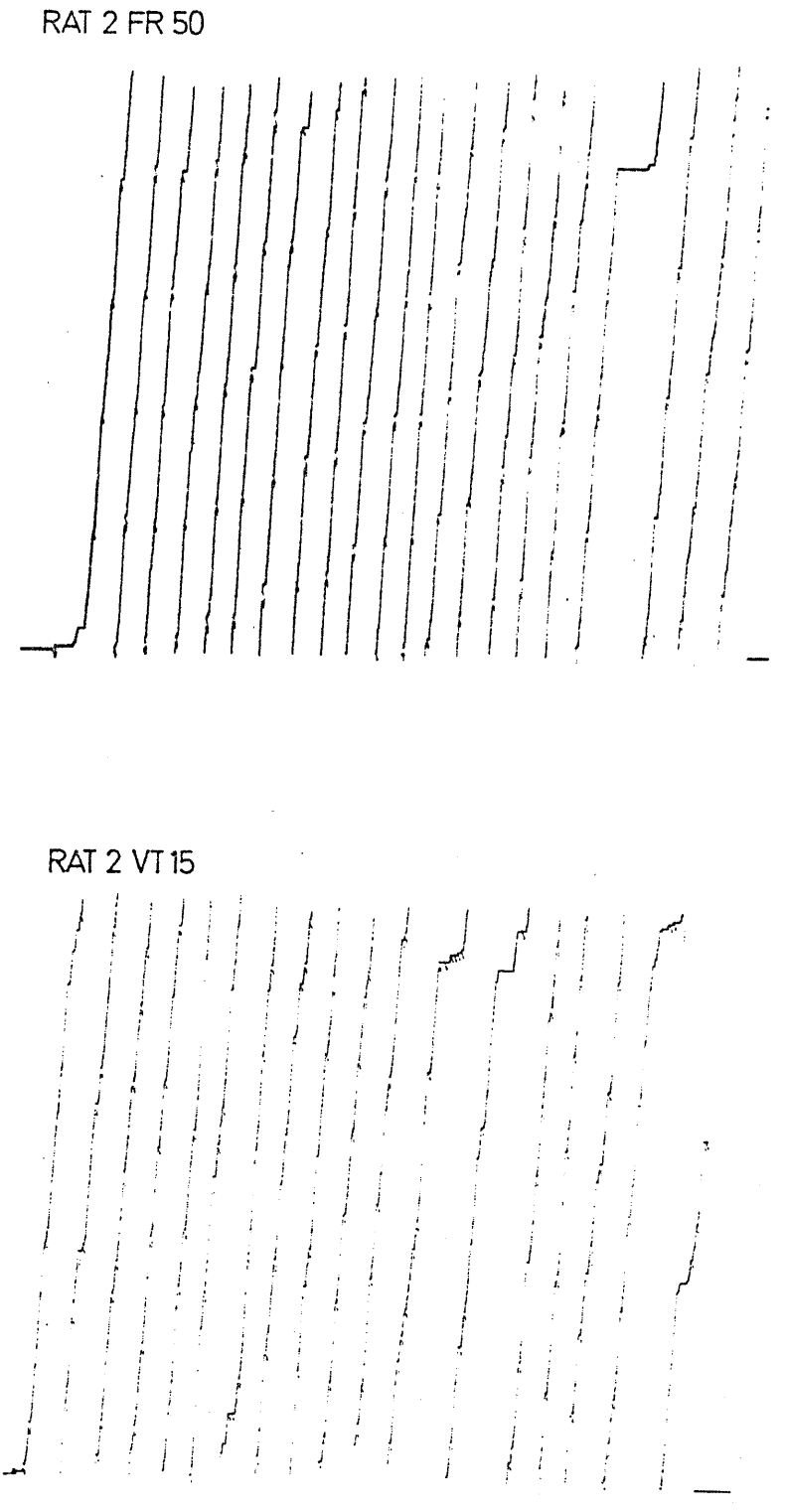


Fig. 5.4b. Representative cumulative records for Rat 2 in Experiment II.

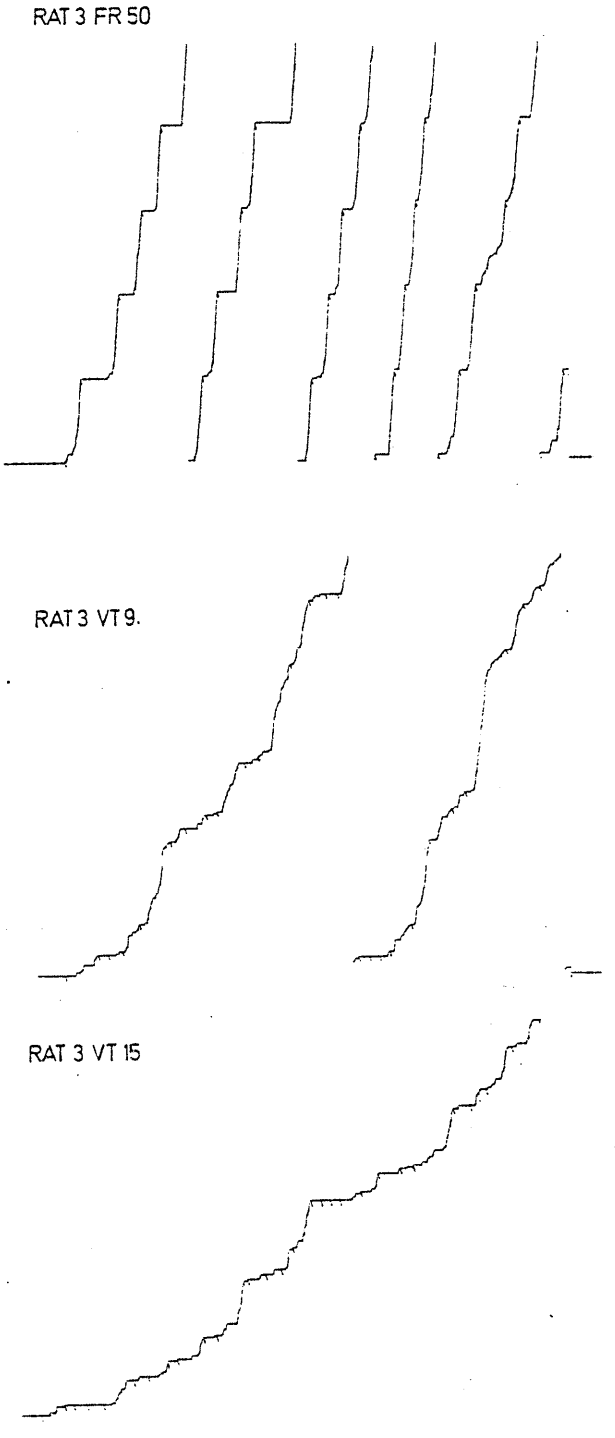


Fig. 5.4c. Representative cumulative records for Rat 3 in Experiment II.

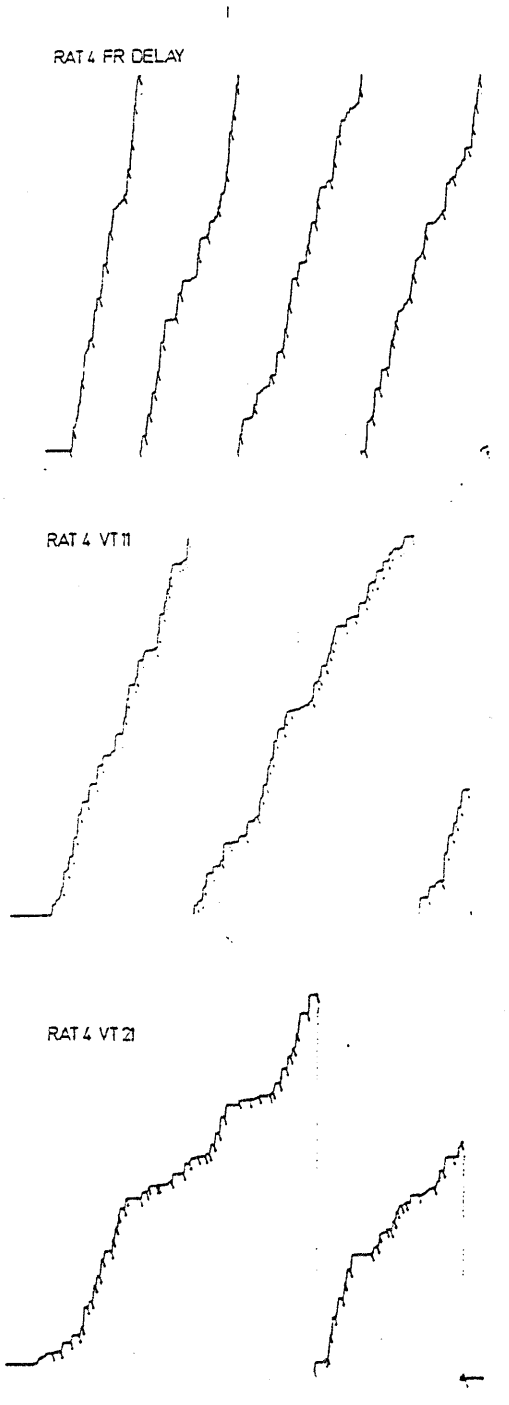


Fig. 5.4d. Representative cumulative records for Rat 4 in Experiment II.

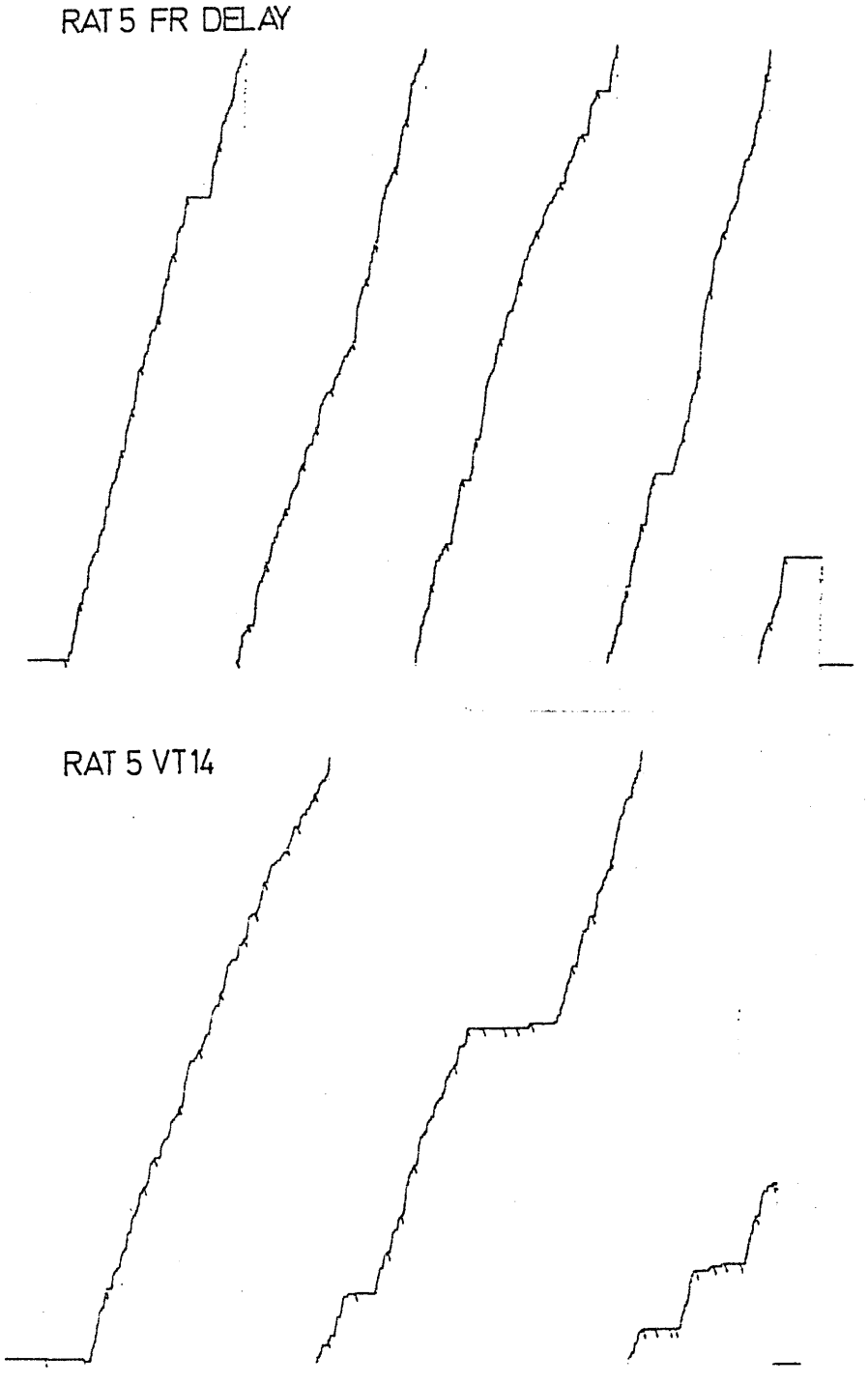


Fig. 5.4e. Representative cumulative records for Rat 5 in Experiment II.

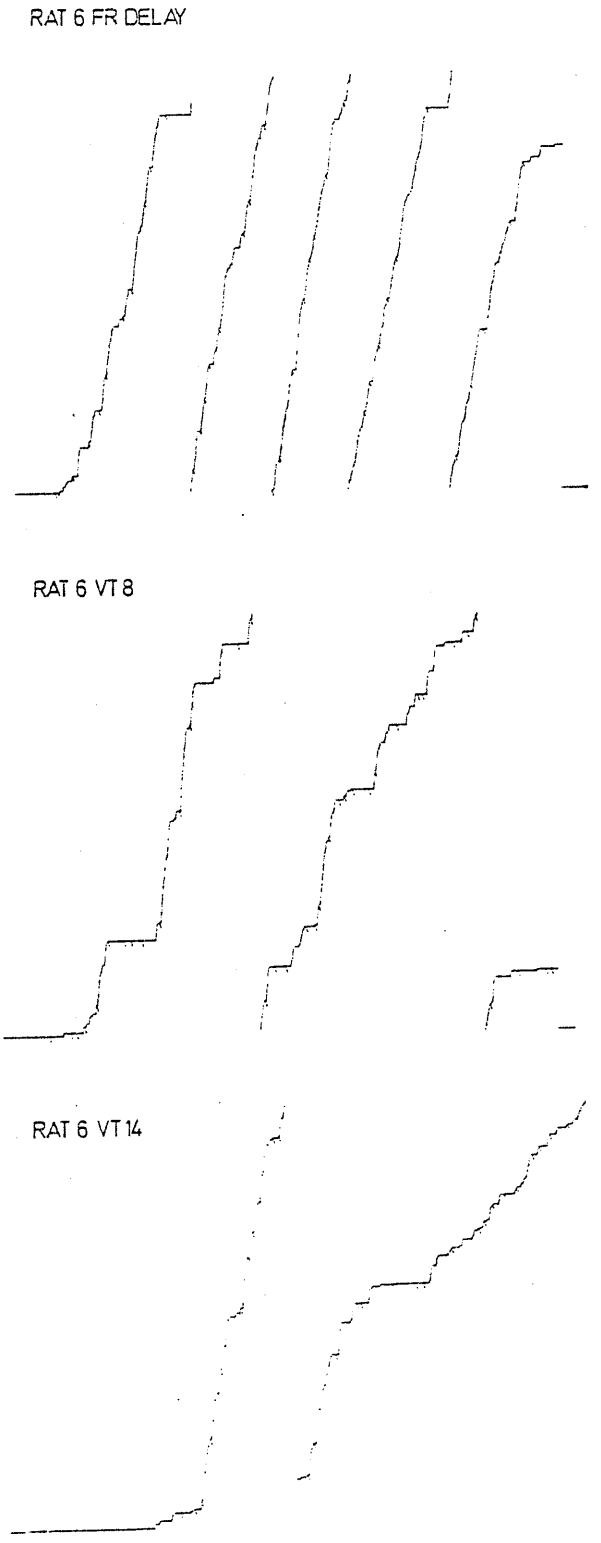


Fig. 5.4f. Representative cumulative records for Rat 6 in Experiment II.

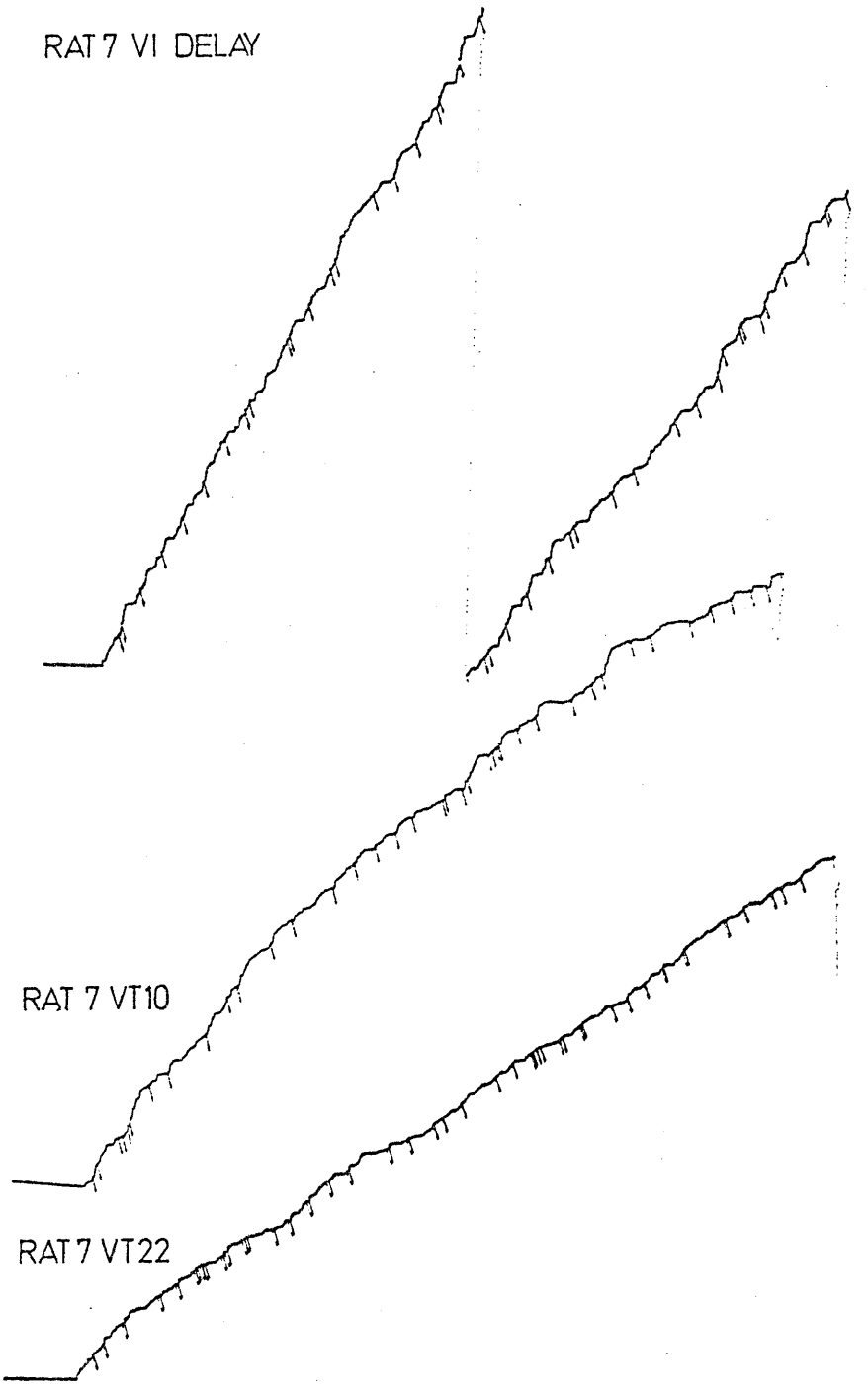


Fig. 5.4g. Representative cumulative records for Rat 7 in Experiment II.

beginning of the session relative to the end of it (Rat 6). Rat 7, the rat exposed to the VI-delay condition, not surprisingly emitted a non-break-run pattern. The effect of the VT schedules was to increase pausing (Rats 4, 5 and 6), accentuate within rate differentials (Rat 6), decrease burst lengths (Rat 4 and 5) and contact lower rates of responding (Rat 7). It also seemed that reinforcement delays increased. This however, is not stated with confidence as it is difficult to assess on the basis of cumulative records.

5.4. Discussion

Overall, the results described in this experiment contradict those found in both the second pilot experiment and experiment I. Delay of reinforcement did not produce greater resistance to the response decrementing effects of VT schedules than did an immediate reinforcement schedule. These data, therefore, conflict with the view proposed by Schoenfeld et al (1973). The results bear a strong resemblance to those found by Sizemore and Lattal (1977). In addition, a FR schedule which induced an atypical pattern of responding produced particularly strong resistance to response-independent reinforcement (see also Edwards et al, 1970).

The most obvious alternative to Schoenfeld et al's (1973) view is that proposed by molar correlation theorists (Baum, 1973; Rachlin, 1978). There are data here, though, that present difficulties for that view too. First, the fact

that the FR schedule produces as good as, if not better, resistance to the VT schedule as do the delay schedules is also difficult for this view to explain. As pointed out in section 2.6.2., response decrement during a VT schedule should occur more slowly after a delay of reinforcement schedule than after training on an immediate reinforcement schedule. Such was not the case in this experiment. Second, the response decrement that did occur was not uniform. Instead cyclicities were present in the data. Williams (1976) has noted that the finding of cyclicities with periodicities of greater than 1, poses a major problem of interpretation for the correlation view.

The results appear to provide some support for the proposition that response rate prevailing during the baseline response-dependent reinforcement schedule is a determinant of subsequent resistance to response-independent reinforcement (Schoenfeld and Farmer, 1970). Reference to figure 5.2 reveals that response maintenance was stronger for Rats 1 and 2 than it was for Rat 3 during the VT phase. Rats 1 and 2 responded at a much higher rate during the FR schedule than did Rat 3. The data from the delayed reinforcement group, however, showed no such relationship. If any trend is present in this group's data, it is the opposite to that predicted by Schoenfeld and Farmer (1970). It therefore seems unlikely that the response rate prevailing during the baseline condition was a major determinant of response persistence in the present experiment.

Associated with rate of responding, but having somewhat more flexible dimensions is the pattern of responding (Shimp, 1975). Examination of cumulative records (fig. 5.4) revealed markedly different patterns of responding. As noted in the results section, the immediate reinforcement group's pattern could be described as being of two kinds. These were either the break-run pattern or a pattern in which high rate responding occurred throughout the majority of IRIs. Only the rat which emitted the break-run pattern during the baseline showed a considerable decrement in responding. Why should the break-run pattern be more vulnerable to the response-decrementing properties of the VT schedule rather than the other pattern? One reason could be that in the former case, VT reinforcers can contact $\not{R}$ in at least two contexts. The first of these is the PRP, while the second is after a period of responding. In the latter case, however, it is likely that the VT reinforcer will only contact $\not{R}$ during the PRP. However, from the baseline records, it is clear that reinforcers set the occasion for a prolonged burst of responding (Rescorla and Skucy, 1969) in the latter case, so that even where the VT reinforcers contacted $\not{R}$, it is likely that a burst of high rate responding will follow, hence response decrement will be very slow in this case. The discriminative properties of the reinforcer in the first case - break-run pattern - would have an opposite effect, thus increasing the speed of response rate decrement. One question which might be posed at this point is why response persistence was so much

stronger for Rats 1 and 2 in this experiment relative to Rats 1 and 2 in the previous experiment after they had been exposed to the VR schedule? The probable answer can be found in the cumulative records from both experiments. Reference to figures 4.4.a and b and 5.4a and b reveals that in the former case - VR schedules - the rats tended to respond more slowly at the end of the session. No such rate differential took place in this experiment. Where the rats do respond more slowly at the end of a session there is of course a greater chance that the VT reinforcers can contact either episodes of $\not{X}$ or longer IRTs. Some evidence for this proposal can be gleaned from the inspection of the cumulative records for the VT schedule after the VR schedule shown in figures 4.4a and b.

A response pattern analysis of this kind might also provide a reasonable framework for explaining the response decrement observed in the delayed reinforcement group. Inspection of the cumulative records reveals that with the exception of Rat 7, PRPs of a reasonable duration were observed for all rats in this group. These patterns differ from those observed in experiment I in which the delayed reinforcement schedule tended to induce short PRPs often followed by local increases in response rate. Reference to cumulative records indicates that the bursts of responding became shorter and the free reinforcers began to intercept longer IRTs. This is particularly noticeable in Rat 7's records. The VT schedule then began to control its own pattern of responding (Zeiler, 1968). The pattern of responding during the

baseline, however, is still an important determinant of subsequent resistance to the response-decrementing properties of the VT schedules, because the VT reinforcers can only influence response patterning if they are permitted to intercept patterns which are different from those observed during the baseline. Where an organism allocates more time to emitting R during the baseline, response decrement is more likely to occur. Where the reverse is the case, response decrement will be slowed. Delay schedules may be correlated with response rate increments during VT because the patterns of responding they induce are more variable than those induced during an immediate reinforcement schedule. The obtained delays during a VT may actually be shorter than those during the response-dependent reinforcement phase. If these shorter delays are associated with local increases in rates then response rate increments may be found. This possibility implies that there may be large intersession variability in response rate (i.e., cyclicities).

A serendipitous observation might be made here. In section 2.6.1.1. and Chapter 3 it was proposed that the matching of temporal distributions as well as rates of reinforcement across response-dependent and response-independent reinforcement conditions might have marked effects on response persistence during VT. The apparatus malfunctions which occurred in this experiment provide some support for that contention. For Rat 2, extra reinforcers were dispensed at very short intervals during sessions 1, 2 and

12 of the VT condition. It can be seen in fig. 5.2 that response rate was reduced in those sessions. Further, as in the first pilot experiment, response rate recovered when reinforcement rate was subsequently reduced. A similar trend is observable for Rat 3.

The type of explanation proposed here to explain the results is a molecular-contiguity based one. It resembles explanations proposed by both Henton and Iversen (1978) and Shimp (1975) in that it focuses on both individual response-reinforcer contiguities and that the response unit can be categorized in terms of IRT durations. This view states that the baseline schedule is only a relevant determinant of subsequent response maintenance under a VT schedule insofar as the pattern of responding which it induces. To the extent that VT reinforcers intercept a similar pattern of responding so response rate will be maintained. Once temporal distribution of VT reinforcers is allowed to contact different temporal distributions of responses, however, the VT schedule will begin to control its own pattern of responding. There may be both large intra- and intersession variability in rates (Davis and Hubbard, 1972). Any change in response rate is likely to be less dramatic after a delay of reinforcement baseline schedule then after an immediate reinforcement schedule because such variability is more likely to have been present during the former condition than in the latter condition.

CHAPTER 6 EXPERIMENT III: TRANSFER FROM A TANDEM FR DRL SCHEDULE TO A VARIABLE-TIME SCHEDULE.

6.1. Introduction

Data from the pilot experiments and experiment I indicate that response rate during exposure to a VT condition is more likely to be maintained at or above the level associated with a prior response-dependent reinforcement schedule when that baseline schedule is an unsignalled variable delay of reinforcement schedule. The results from experiment II question the sufficiency of this statement when the comparison made is between rate of responding during the VT condition with that obtaining during a prior response-dependent reinforcement phase. It should be noted, however, that if the comparison made is that between the VT and subsequent response-dependent phases then response rate is generally comparable across conditions for the delayed reinforcement group (see Fig. 5.1 - Rats 5, 6 and 7) but not for the immediate reinforcement group. If the criterion used is the one just mentioned then the delay schedule was associated with greater resistance to response-independent reinforcement than the immediate reinforcement schedule. It should be noted, however, that such a criterion should be used with caution because rates of reinforcement are not equated across conditions. Given the difficulty in recovering baseline rates of responding with delay schedules in particular, it is unlikely that such equality would be obtained.

One reason why a delay of reinforcement schedule produces greater resistance to response-independent reinforcement could be that the pattern of responding induced by an immediate reinforcement schedule is more easily disrupted than one induced by a delay of reinforcement schedule. This is so because organisms exposed to a delay schedule have experienced contiguities between both R and $\not{R}$ with reinforcement. When the baseline schedule is an immediate reinforcement one, only response-reinforcer contiguities are possible, although instances of $\not{R}$ are free to occur. In experiment II, response maintenance was best for those rats in whom the FR schedule induced an atypical pattern of responding. They both responded at very high rates throughout the session. Despite that, an appreciable response decrement still occurred. It may be the case that in order to obtain either no response decrement during VT or a response rate enhancement, a baseline schedule in which at least two response classes can be reinforced must be used. This is the case because delays of reinforcement could in fact be reduced during the VT schedule relative to the baseline condition. Generally, there is an inverse relationship between response rate and duration of reinforcement delay (Renner, 1964).

It is hypothesized by Schoenfeld et al (1973) that during an unsignalled variable delay of reinforcement both members of the designated operant and other behaviours can be strengthened. It is possible, however, to strengthen two distinct response classes without using a delay of

reinforcement schedule. Further, this can be achieved by allowing members of only one of the classes to be contiguous with reinforcement. An arrangement which produces such an effect is the spaced-responding type of schedule (e.g., DRL) where duration of IRT is the property of behaviour which is reinforced. Typically, under such schedules, more than one response class emerges - the lever press/key peck (behaviour contiguous with the reinforcer) and some other stereotyped form of behaviour (adjunctive or interim behaviour; see Kramer and Rilling, 1970). Usually, such schedules induce low absolute rates of responding (depending on the DRL value) while the IRT distributions are typically bimodal with peaks at the reinforced IRT value and at very short values. The question which arises here is whether it is necessary that both response classes be contiguous with the reinforcer during the baseline if resistance to response-independent reinforcement is to be produced. This case is of particular interest because under these kinds of schedules rates of responding are usually low, and the animal normally allocates more time to emitting $\not{R}$ rather than R.

In the present experiment, the transition from a schedule in which the contingency demands a period of not-responding bounded by the emission of a member of the designated operant to a matched VT schedule is examined. The baseline schedule being described here is a tand FR1 DRL schedule. There is little evidence concerning this type of schedule (Lowe, 1974; Mechner and Guevrekian, 1962), and there have

been no published accounts of transitions from it to VT schedules. Nevertheless, it could be argued that to the extent that response persistence is determined by the presence of a variable delay of reinforcement during the baseline, this type of schedule should be correlated with substantial response decrement. Alternatively, it could be the case that schedules which demand the presence of at least two response classes (rather than permitting them to occur) might lead to stronger resistance to response-independent reinforcement. In this case, this kind of schedule will be correlated with response persistence under VT schedules.

6.2. Method

Subjects

Three male Lister hooded rats which were about 6 months of age at the beginning of the experiment. They were maintained at about 85% of their free feeding weights. They were individually housed and water was available *ad lib* in their home cages. All were experimentally naive.

Apparatus

The same as in experiment II.

Procedure

The rats were allowed to explore the chamber for one hour. During this session the food trough was filled with food pellets. They were then exposed to a concurrent FR1 VT90sec schedule for one session. Those rats which did not press

the lever were then shaped to lever press by the method of successive approximations. Following this they were exposed to a series of tandem fixed-ratio fixed-interval schedules (tand FR FI) where the FR parameter was always 1 and the FI parameter was gradually increased from 5 to 20 sec over 17 sessions. They were then given training on the tand FR1 DRL schedule where the DRL parameter was increased from 5 sec (14 sessions) to 8 sec (6 sessions) to 10 sec. This schedule was kept in effect for 34 sessions, and is called the baseline schedule. The rats were then exposed to 15 sessions of VT reinforcement. To produce the VT schedule the interreinforcement intervals occurring during the last 6 baseline sessions were recorded and VT tape was prepared using these values. The animals were then returned to the baseline schedule for 14 sessions. Experimental sessions took place five days per week and session duration was normally 30 minutes.

6.3. Results

Rate of lever pressing and entering the tray during the last 6 sessions of baseline and all sessions of the VT phase are shown in figure 6.1. On the transition to the VT schedule, there was a rise in response rate for all rats. After the second VT session, however, response rates begin to diverge. For Rat 11 there is a consistent decrease in response rate over the VT sessions, while for Rat 13 there is an abrupt increment in response rate which is maintained throughout the VT phase. Rat 12 shows a slight decrement in lever pressing, with rate of responding stabilizing at about 65%

of the mean baseline rate. The relationship between rate of tray entry and lever pressing is inconsistent, with two rats showing a direct relationship and the third (Rat 12) showing an inverse relationship. Both rate of lever pressing and entering the tray were recovered on the return to baseline.

Figure 6.2. shows the duration of the PRP during the final 3 sessions of each condition as well as responses per reinforcer (an efficiency index) and tray entries per reinforcer. The last two measures were based upon the last 5 sessions of each condition (i.e., means). In all cases, the mean PRP value was higher during the VT condition relative to both baseline determinations. Mean PRP duration during the baseline does not seem to be related to subsequent resistance to response-independent reinforcement. With reference to the responses per reinforcer measure, none of the rats achieved perfect performance (2 responses per reinforcer) during the baseline phase, although both Rats 11 and 13 did approach it. For both of the rats which showed response decrement, the mean number of responses per reinforcer was somewhat lower during the VT schedule relative to the baseline determinations. The means in fig. 6.2, however, include IRIs without a response. If these are excluded then the adjusted means during the VT phase are as follows: Rat 11 - 1.83; Rat 12 - 3.92; and Rat 13 - 5.40. This arithmetic manipulation does not substantially alter the trends already present. The results for the tray entry per reinforcer measure shows an interesting trend in that there appears to be an inverse relationship between the

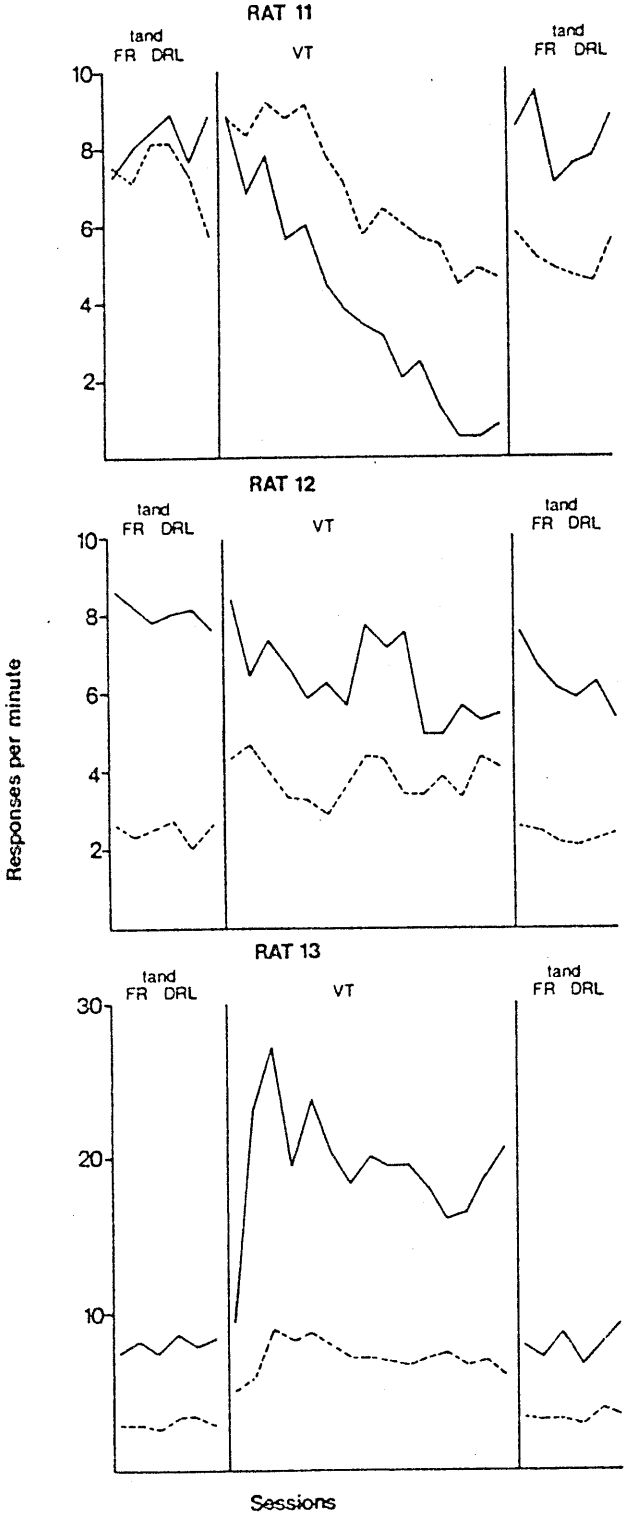


Fig. 6.1. Rate of lever press responding and tray entries during each schedule condition. Solid lines indicate the lever press response, dashed lines indicate tray entries.

number of tray entries per reinforcer during the baseline and subsequent resistance to response-independent reinforcement.

The relationship between rate of lever pressing during the VT phase and the proportion of IRIs without a response was assessed by use of the Spearman rank differences correlation. These were as follows: Rat 11 - -0.98; Rat 12 - -0.76; and Rat 13 - +0.03. The correlations for Rats 11 and 12 are significant at the 1% level. The low correlation for Rat 13's data can be accounted for on the basis of the small number of IRIs without a response (there were only 29 intervals out of a possible 1529 in which this rat did not press the lever).

6.4. Discussion

The results indicate that a delay of reinforcement schedule is not a necessary requirement for producing a response rate increment during a VT condition. Rat 13 consistently emitted a higher rate of responding during every VT session relative to the prior baseline phase. One of the other rats also showed strong resistance to the VT schedule. The result from Rat 13 is the first reported case in which a consistent and maintained response rate increase occurred during a VT schedule relative to an immediate reinforcement baseline in the absence of any differential stimulus-reinforcer contingencies or any change in the rate of reinforcement (Lachter et al, 1971). The data here also indicate that resistance to response-independent

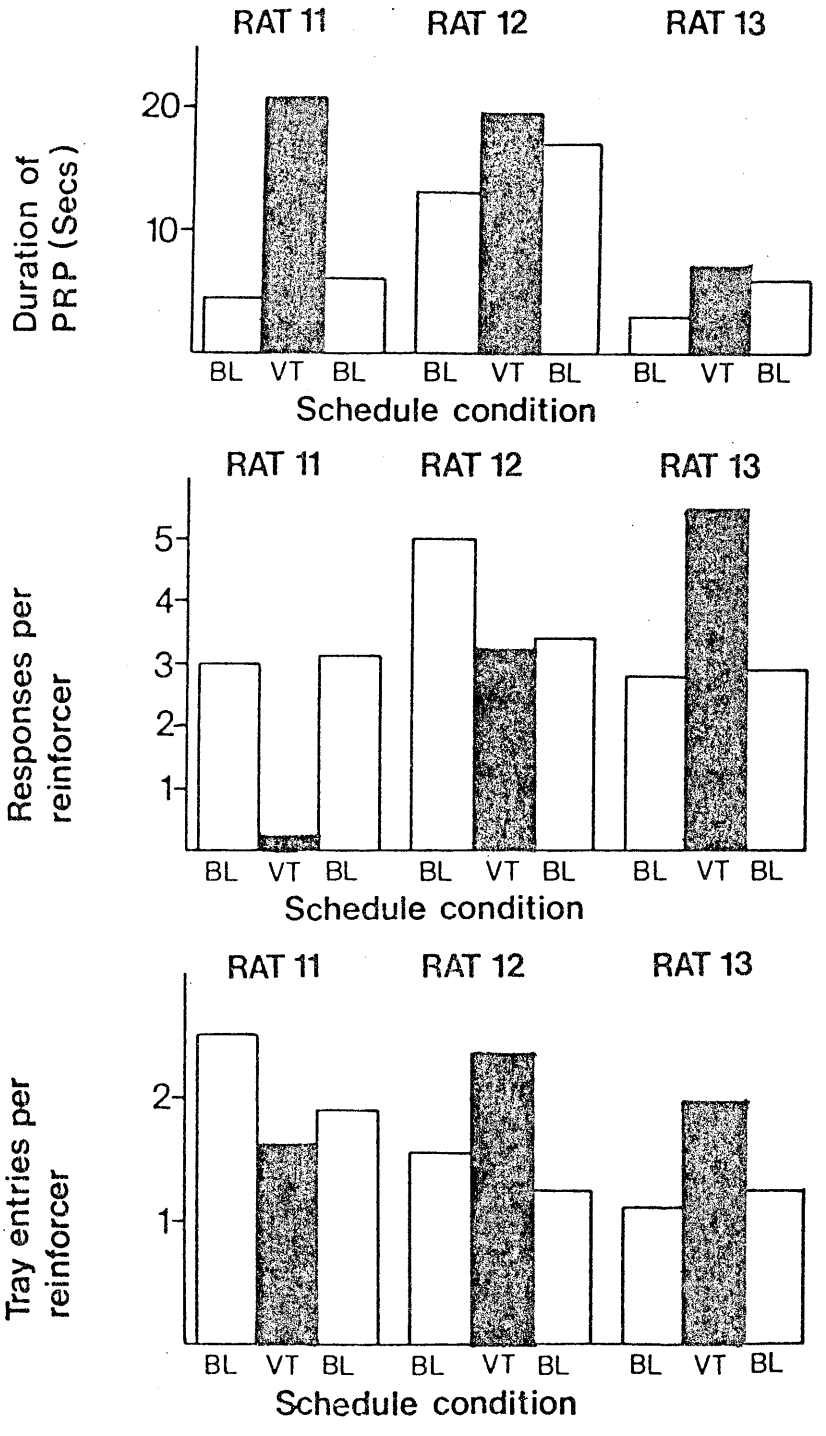


Fig. 6.2. Mean duration of postreinforcement pause, mean number of responses per reinforcer and mean number of tray entries reinforcer for each rat under each schedule condition. BL refers to the baseline tand FR1 DRL 10" schedule, VT refers to the variable-time schedule.

reinforcement can be achieved even in the case where the baseline schedule induces both a low rate of responding and a pattern in which the organism is required to allocate more time to emitting behaviours other than the one which will be contiguous with the reinforcer. These data then provide further evidence against the view that a low rate of responding during baseline is likely to be followed by response decrement on the transfer to a VT schedule (Schoenfeld and Farmer, 1970).

Davis et al (1973) have suggested that efficiency of responding during the baseline is inversely related to subsequent resistance to response-independent reinforcement. The results reported here contradict that view. Rat 13 was marginally the most efficient responder during the baseline, followed by Rat 11 and Rat 12. The results show that Rat 11 showed the least resistance to the response-decrementing effects of response-independent reinforcement, while Rat 13 clearly showed the most. Davis et al (1973) used a DRL as their baseline schedule and adopted the same efficiency index as used here. It could be argued, however, that this index does not totally reflect efficiency of responding. A better index might be number of reinforcers earned. Taking that index here results in exactly the same kind of ordering. The mean number of reinforcers earned by each rat during the last 3 sessions of baseline were as follows: Rat 11 - 87; Rat 12 - 48; and Rat 13 - 98.3. Therefore efficiency of responding during baseline seemed to have

little effect on subsequent resistance to the VT schedule.

The sole baseline measure which seemed to have some predictive value was the tray entries per reinforcer measure. The effectiveness of this variable might be mediated by the temporal distribution of the tray entry response. Where the ratio was low - as in the case of Rat 13 - it could be the case that the rat was only entering the tray after the food pellet had been delivered. In the case where the ratio was high, it could be the case that the behaviour was emitted after the first response had occurred but before the next. In the latter example it would be reasonable to predict that such behaviour (i.e., tray entry) would have increased during the VT schedule because entering the tray would have been closer to the delivery of the reinforcer. Such an inverse relationship was only apparent for Rat 12. For Rat 11, where response decrement was most severe, rate of tray entry behaviour declined over the VT sessions. It is possible that this behaviour changed in topography such that the duration of tray entry actually increased. If this were so then the inverse relationship would be preserved. Without any measurement of tray entry duration, however, this account must remain speculative. Data from Rat 13 indicate that tray entry and lever pressing are not necessarily incompatible.

Of the possible outcomes mentioned in section 6.1, the second seems to have received most support. Two major implications follow from these results. First, the type of

baseline schedule per se may be irrelevant with respect to producing subsequent response persistence in the present context. What does appear to be of importance is the pattern of responding induced by the baseline schedule and how that pattern interacts with the VT reinforcers (Henton and Iversen, 1978). In the case where the response unit required is an IRT, then the effect of allowing free reinforcers to intercept behaviours other than the one contiguous with the reinforcer during the baseline may not be as deletarious as using a baseline schedule in which R is free to occur but is not required. In the former case a sequential relationship between instances of R and $\not{R}$ are likely to be formed. To the extent that free reinforcers contact $\not{R}$ of the same topography as had occurred during the IRT schedule, so the pattern of responding will remain undisrupted. If there is a large discrepancy, however, between the proportion of reinforcers which are contiguous with the designated operant (i.e., lever press) when the baseline and VT phases are contrasted, then it is likely that the IRT distribution will change and response decrement will occur (i.e., longer IRTs will predominate).

The results from this and the other experiments (especially experiment II) indicate that a more molecular approach is probably required in order to analyse the effects of VT reinforcers upon a response previously maintained by response-dependent reinforcement. In experiment IV, an IRT analysis is attempted.

CHAPTER 7 EXPERIMENT IV: TRANSFER FROM A DRL SCHEDULE TO A VARIABLE-TIME SCHEDULE.

7.1. Introduction

The results from experiment III revealed that exposure to a tand FR1 DRL10sec schedule led to a great deal of variability in responding during a subsequent VT condition. Although it was argued that the results from that experiment had important implications for theories of response-independent reinforcement, the considerable variability indicates that the controlling variables are not to be found solely in the baseline schedule. It appeared that a more molecular approach might be a profitable one to adopt.

In the present experiment the transition from a simple DRL to a VT schedule is examined. The available evidence on such a transition is sparse and somewhat mixed. Davis et al (1973) trained rats on a DRL20sec schedule prior to transferring them to a matched VT schedule. They found a rapid and marked decrement in lever press responding. Efficiency of responding during the baseline was inversely related to resistance to response-independent reinforcement. Davis et al (1973) were also able to demonstrate that response decrement during VT was associated with an increase in the relative frequency of long IRTs. Nevin (1979b), however, has shown that DRL schedules produce greater response strength than a differential-reinforcement-of-high rates (DRH) schedule when the indices of response strength were resistance to both extinction and a free food

manipulation. Nevin's (1979b) schedule conditions were highly complex in that they involved superimposing both the DRL and DRH schedules onto VI schedules of differing reinforcement rates within the context of a multiple schedule format. Further the VT condition was only in operation for one session at a time (i.e., baseline schedules were intersperesed), and it was presented for 30 sec periods between components of the multiple schedule. It is therefore impossible to directly compare the results from the experiments conducted by Nevin (1979b) with those found by Davis et al (1973).

In the present experiment, all events are programmed by computer. This allowed assessment of IRT distributions as well as obtained delays of reinforcement during the VT phase. It seems reasonable to predict that where response decrement appears there will be an increase in the relative frequency of long IRTs (Davis et al, 1973). Further, to the extent that demanding two response classes is an important determinant of resistance to response-independent reinforcement, so the use of DRL schedule should lead to unusually strong resistance to a subsequent VT schedule.

7.2. Method

Subjects

Three male Lister hooded rats which were about 6 months of age at the beginning of the experiment. They were maintained at about 85% of their free feeding weights. They were individually housed and water was available ad lib in

their home cages. All were experimentally naive.

Apparatus

Apart from the fact that all experimental events were controlled and recorded by a Data General Nova computer, the apparatus was the same as in the previous experiment.

Procedure

The procedure was exactly the same as in the previous experiment save the following exceptions. Once the rats had acquired the lever press response they were exposed to a DRL schedule, the value of which was increased over 5 sessions to 10 sec. This value was retained for a further 40 sessions. The rats were then exposed to a VT schedule matched in terms of the temporal distribution and frequency of reinforcement which obtained during the final 6 sessions of the baseline schedule. The VT phase lasted for 15 sessions. The rats were then returned to the DRL10sec schedule for 15 sessions. Experimental sessions took place five days per week and session duration was normally 30 minutes.

7.3. Results

Mean rate of lever pressing over the last 5 sessions of the baseline conditions and the mean rate of responding and delay of reinforcement in all of the VT sessions are shown in figure 7.1 (missing data points represent data lost by the computer). There was an apparatus failure for Rat 14

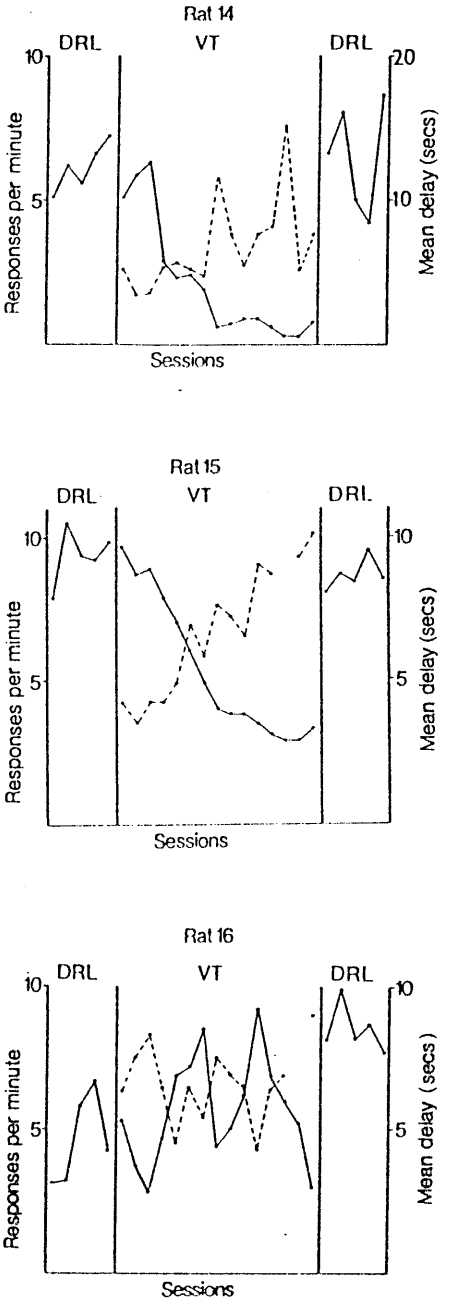


Fig. 7.1. Mean rate of lever pressing and delay of reinforcement during each schedule condition. Solid lines indicate the lever press response, dashed lines indicate duration of reinforcement delay.

during session 3 of the VT phase which took the form of the pellet dispenser remaining open. The rat was withdrawn after 5.4 min of this session. Responding all but extinguished in one rat (Rat 14), for Rat 15 there was a relatively slow decline in response rate with a levelling off at above zero level, while for Rat 16 response rate during the VT condition took a cyclical form, although the periodicities were unequal. A fair proportion of the VT sessions were associated with a higher rate of responding relative to mean of the last 5 baseline sessions. Autocorrelations with lags of 1, 2 and 3 were calculated for the response rate data. The values of the lag 1 autocorrelations were 0.78, 0.83 and 0.38 for Rats 14, 15 and 16 respectively. None of these reached an acceptable level of statistical significance. The lag 2 and 3 autocorrelations were positive for both Rats 14 and 15, whereas they were both negative for Rat 16 (-0.1 and -0.42 respectively). Taken as a whole, and with due regard for the lack of statistical significance, these autocorrelations indicate that response decrement was reasonably stable and consistent for both Rats 14 and 15. No such trend is present in Rat 16's data. Inspection of fig. 7.1 reveals that there was a close relationship between mean response rate and mean reinforcement delay. The visual impression is confirmed by Spearman rank difference correlations. The values of these were: -0.71, -0.92 and -0.86 for Rats 14, 15 and 16 respectively. All of these are significant at the 1% level (one-tailed test). As in experiment III, correlations were calculated between rate of responding during the VT

condition and the proportion of IRIs without a response. The following values emerged: Rat 14 -0.96; Rat 15 -0.95; and Rat 16 -0.82. Once again these are all significant at the 1% level.

Figure 7.2 provides details concerning mean PRP duration and efficiency of responding during the final 3 sessions of each experimental phase. Mean PRP duration for all rats during the baseline phases was very close to the DRL value. Changes brought about by the VT schedule were not consistent. In two rats there was a slight decrease in PRP duration during the VT condition while for the third there was a slight increase. In terms of efficiency of responding, all of the rats adjusted well to the DRL schedule with a high proportion of the reinforced responses terminating the PRP (range from 60 to 80% of IRIs). Once the constraints inherent in the DRL schedule had been removed, however, 'efficiency' of responding decreased. The means shown in fig. 7.2 include IRIs without a response. If these are excluded, then the proportion of IRIs containing only 1 response were as follows: Rat 14 0.81; Rat 15 0.49; and Rat 16 0.28. With the exception of Rat 14, who hardly responded at all during this phase of the experiment, this arithmetic manipulation does not materially alter the impression provided by fig. 7.2. It would seem then that the pattern of responding changed from the baseline to the VT condition.

The change in response patterning suggested by the data depicted in fig. 7.2 is confirmed in figs. 7.3a and b. In these, IRT distributions (both overall and reinforced) for Rats 15 (figure 7.3a) and 16 (figure 7.3b) are presented. Rat 14 was excluded because of the apparatus failure and his very low rate of responding. The IRT distributions were calculated as follows. The VT phase was divided into 5 blocks of 3 sessions each. The means of these 3 sessions were then calculated. The IRT distributions for the DRL schedule were based upon the final 3 sessions of the first baseline. Unfortunately some data were lost. These were VT blocks 1, 2 and 5 for Rat 15 reinforced IRTs and block 5 of the overall IRT distribution. All of these were based upon 2 sessions data. VT block 5 both reinforced and overall distributions for Rat 16 was also based upon two sessions data. Figure 7.3a reveals that the reinforced IRT distribution for Rat 15 was peaked at the DRL value; while fig. 7.3b reveals two peaks on this measure for Rat 16. These are at the DRL value and the 20+sec bin. The overall IRT distributions show that short IRTs (less than 1 sec) occurred at a relatively high frequency for both rats during the DRL condition. Introduction of the VT schedule shifted both distributions to the left for both rats. By VT block 3, however, there is a reduction in the relative frequency of short IRTs for Rat 15. By block 5, the most frequently occurring IRTs are those in the 3-4 and 20+sec bins. Rat 16 shows a somewhat different pattern. For this rat, the shortest IRT value remains the most frequently occurring throughout the VT phase, although its relative frequency

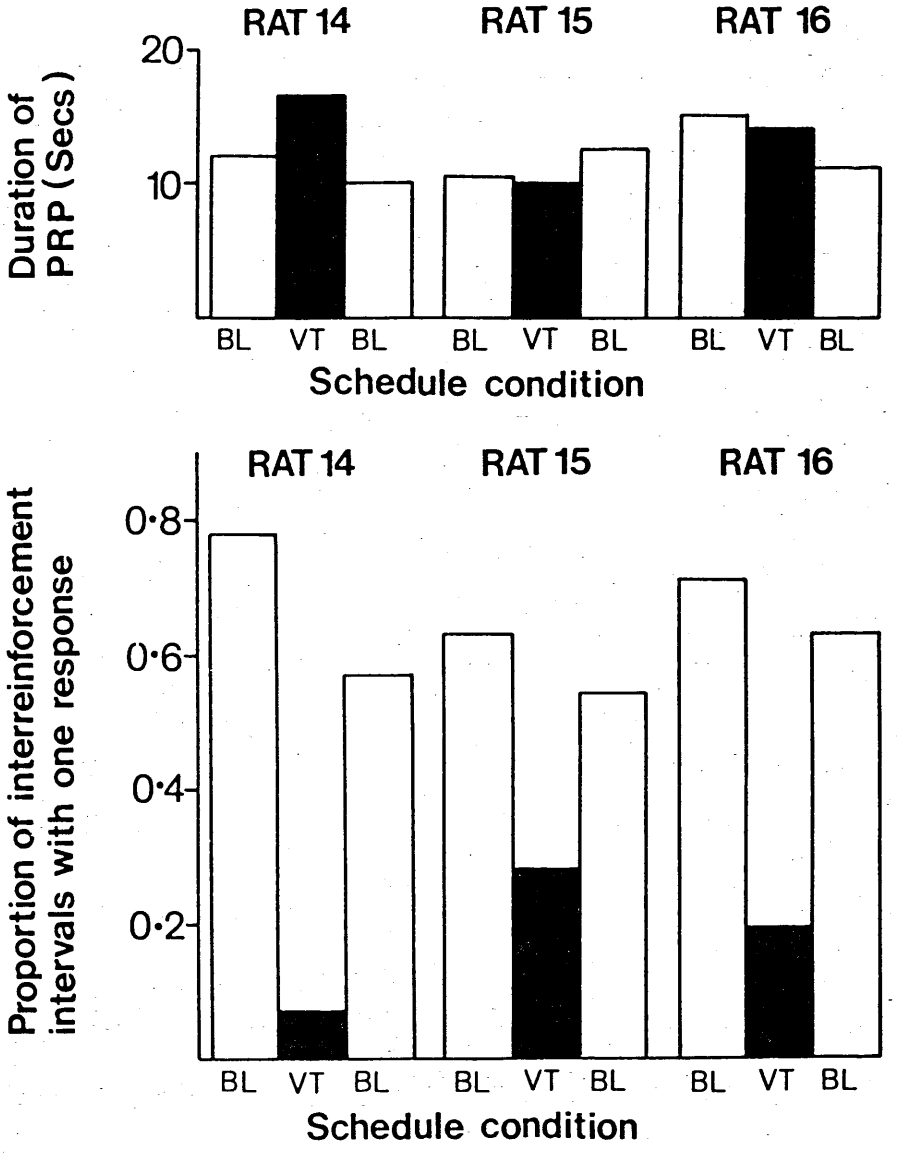


Fig. 7.2. Duration of postreinforcement pause and efficiency of responding for each rat during each schedule condition. BL refers to the baseline DRL10 sec schedule, VT refers to the variable-time schedule.

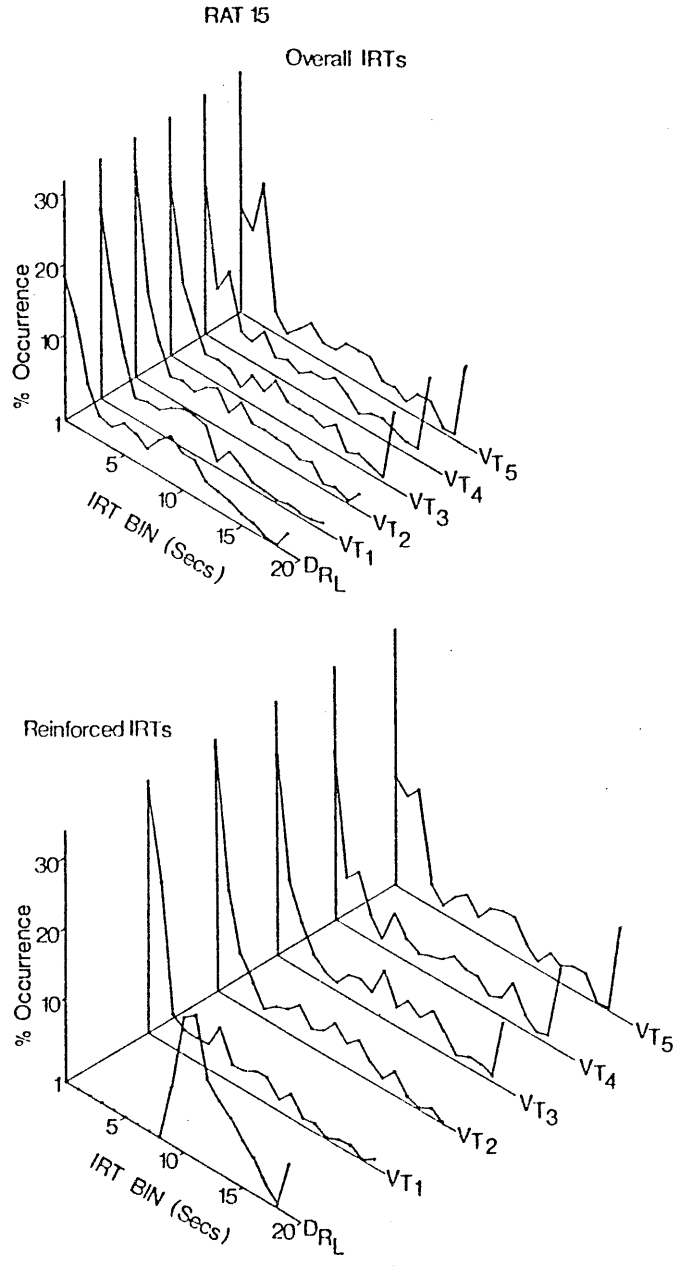


Fig. 7.3a. Overall and reinforced IRT distributions for Rat 15. Schedule abbreviations are explained in the text.

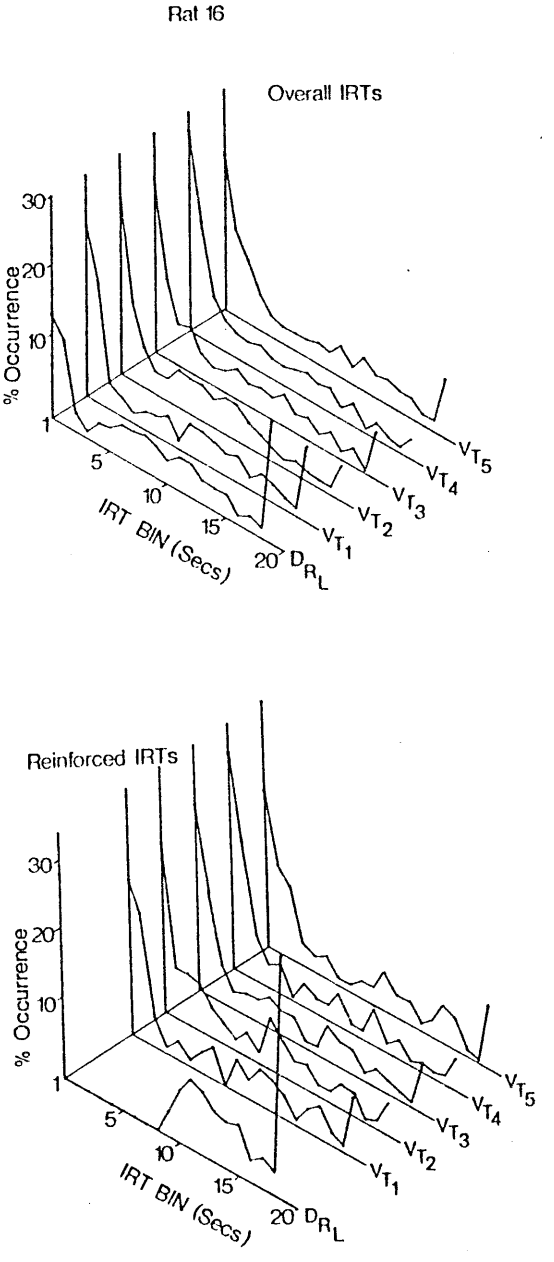


Fig. 7.3b. Overall and reinforced IRT distributions for Rat 16. Schedule abbreviations are explained in the text.

drops slightly by VT session 5. There is an increase in the relative frequency of long and middle range IRTs. The IRT distributions for Rat 16 appear to reflect the cyclities evident in the response rate data (see fig. 7.1.). Overall, there is a close relationship between the reinforced and overall IRT distributions. These data also indicate that the VT schedule controls the pattern of responding. Further, these patterns show orderly changes with changes in response rate.

7.4. Discussion

This experiment along with the previous one are the first to be reported in which either no obvious response decrement or a response rate increase during a VT condition relative to an immediate reinforcement schedule baseline has been found. The only other case in the literature which has approximately similar findings is one in which there were differential stimulus-reinforcer contigencies and changes in reinforcement rates across the response-dependent and response-independent conditions (Lachter et al, 1971). It seems then that schedules which either demand two distinct response classes, or allow more than one response class to be reinforced are more likely to lead to greater resistance to response-independent reinforcement than are those schedules which demand the emission of only one response class.

The data from the IRT distributions confirm the expectations stated in section 7.1. As response rate decrement increased

so the IRT distributions shifted to the right. This was especially noticeable for Rat 15. A similar trend is observable for Rat 16, where VT sessions associated with relatively low rates were associated with an increase in the relative frequency of mid-range IRT durations (i.e., short IRTs were replaced by those in the middle range). The IRT measure then proved useful in a situation in which IRTs were not selectively reinforced by the schedule (i.e., the VT schedule).

The relationship between delay of reinforcement and response rate is a very strong one. All of the correlations between these measures were significant at the 1% level. There was also a strong relationship between response rate during VT and the proportion of IRIs without a response. It is probably the case that these two measures (i.e., reinforcer delay and IRIs without a response) are quite closely related in that, in both, behaviour other than the designated operant is contiguous with reinforcement. It should be noted here that delay of reinforcement does not necessarily lead to response decrement. For example, Rat 16 emitted a higher rate of responding on about half of the VT sessions relative to the mean of the preceding 5 baseline sessions. Obviously, reinforcement delay was longer during the former schedule condition relative to the latter, where it was immediate. The higher rate during the VT sessions would then seem to be mediated by the duration of the IRT which was reinforced. In the present experiment that could be no

shorter than 10 sec during the baseline schedule. Once the constraints of the DRL schedule were removed, however, any duration of IRT could be reinforced. Shorter IRTs were indeed reinforced by a VT schedule. Response decrement in the present experiment seems to be caused by a combination of the delay of reinforcement during the VT schedule, the proportion of IRIs without a response and the duration of the IRTs which are reinforced. All of these variables either affect response patterning or reflect its importance and serve to confirm Schoenfeld and Farmer's (1970) contention that the interaction between responding and other behaviour is crucial in this kind of situation.

The data from this experiment provide some confirmation for the view that IRTs may be a fundamental dimension of behaviour (Shimp, 1975). It is clear that although the VT schedule is not programmed to shape different IRT durations, a strong relation still exists between the overall and reinforced IRT distributions. The use of a more molecular level of analysis has been vindicated.

CHAPTER 8 EXPERIMENT V: TRANSFER FROM FIXED AND VARIABLE DELAY OF REINFORCEMENT SCHEDULES TO VARIABLE-TIME SCHEDULES.

8.1. Introduction

In the last two chapters, experiments were described in which immediate reinforcement schedules which demanded the occurrence of at least two response classes in a specified sequence were used as the baseline condition. The question which was posed in those experiments was whether such a constraint would affect resistance to response-independent reinforcement. The results revealed that it did. One rat consistently responded at a much higher level (in terms of rate of responding) during the VT condition relative to both baseline determinations, a second rat did not show response decrement, while a third seemed to show a decrement in level of responding but no major change in trend. These results departed from those in previous experiments in which an immediate reinforcement schedule had usually been associated with a considerable decrement in responding during a subsequent VT condition (see also Boakes, 1973: Catania and Keller, 1981; Sizemore and Lattal, 1977). It therefore seems likely that where an immediate reinforcement schedule demands the emission of two response classes (instead of merely allowing them to occur) there is a greater probability of finding resistance to the response decrementing properties of VT schedules. Notwithstanding these results, there were also cases of marked response decrements on the transition to VT schedules from a spaced-

responding reinforcement schedule. This could be due to differential delays of reinforcement during the VT schedule, the topography of the response classes which were shaped and maintained during the baseline schedule or some combination of both. Whatever the reason for the differential interorganism resistance to the VT schedules, the results from experiments III and IV are the first cases in the literature to be reported in which there was either no response decrement or response rate enhancement during VT relative to an immediate reinforcement baseline schedule in the absence of differential stimulus-reinforcer contingencies.

The present experiment explores the interaction between R and $\not{R}$ further. In all of the experiments reported so far, the delayed reinforcement schedule used has been of the unsignalled variable variety. Although the effects of signalling were excluded in the rationale (Chapter 3), the use of other ways of arranging reinforcement delays were not. Unsignalled delayed reinforcement schedules can be of two kinds - those in which the delay is either fixed or variable (a nonresetting fixed delay is here called a variable delay because the obtained delays between the response and reinforcer will in fact vary. The term fixed delay is used to refer to a resetting delay procedure, where the obtained delay is of a fixed temporal duration). In the former case, although the emission of both R and $\not{R}$ are required for reinforcement, only $\not{R}$ can be contiguous with the reinforcer. This kind of schedule then is the obverse

of the DRL schedule (as long as only 1 R-occurrence is required for reinforcement). The question which arises from this is whether the different ways of scheduling delay of reinforcement will produce differential resistance to response-independent reinforcement. It would seem that correlation theory (e.g., Baum, 1981) would predict that it would because it should be easier for the organism to discriminate between a resetting delay of reinforcement schedule and VT schedule than between a variable delay of reinforcement schedule and a VT schedule. Contiguity theory, on the other hand, makes no direct prediction. Nevertheless, it is possible to deduce that since the delays of reinforcement may be reduced during the VT sessions relative to the baseline in the fixed delay condition, a response rate increment may become evident. It is possible, however, that the reverse may take place in which case response decrement would occur. This theory would have to predict that the eventual outcome would largely depend upon the response-reinforcer contiguities during the VT sessions (Henton and Iversen, 1978). A level of analysis which is more molecular than one involving the use of simple response rate measures appears to be required. In order to achieve this event recordings were taken of the baseline and VT conditions and an analysis based upon that proposed by Henton and Iversen (1978) was carried out. This allows the writer to predict that to the extent that there were a greater proportion of contiguities between the designated response (lever press) and reinforcement during VT relative to the baseline, so there would be a greater chance of

obtaining either no response decrement or a response rate enhancement.

8.2. Method

Subjects

Four male hooded rats of about 6 months of age at the beginning of the experiment. They were maintained at 85% of their free feeding weights. All animals were individually housed and water was available ad lib in their home cages. All were experimentally naive.

Apparatus

Four identical two-lever Campden Instruments rodent test chambers which have already been described in Chapter 4. In addition 4 Campden Instruments six pen event recorders (model 650) were used to monitor the behaviour of the rats. The gear boxes of the original recorders were replaced by ones which ran the motors at 2 rpm. In addition to the event recordings, behaviour was also monitored by conventional electronic counters.

Procedure

The rats were allowed to explore the chambers for one hour. During this session the food trough was filled with food pellets. One rat (Rat 89), required a further habituation session before he would eat regularly from the trough. The rats were then exposed to a conc FR1 VT90 sec schedule for one session. Those rats which did not press the lever were then shaped to do so by the method of successive

approximations. The rats were then formed into 2 pairs. One of each pair became a 'master' rat, while the other was yoked to it. The master rats were exposed to a tand FR1 DRO schedule (called a fixed-delay - FD - schedule). This was programmed such that a lever press gained access to the DRO component. Any lever presses during the DRO component reset the timer. A period of non-lever pressing activity which met the DRO requirement produced the reinforcer. The yoked rats were linked to their 'masters' in terms of reinforcer delivery. Thus the schedule they were exposed to was functionally a tand FR1 VT schedule - note that they were required to emit at least 1 response between reinforcer deliveries. The range of delays for the yoked animals had limits of from 0 to infinity, i.e., they could be exposed to delays which were in excess of those experienced by the master rats. The initial DRO value was 2 sec. This was increased for the Rat 83/81 pair as follows : 3 sec (5 sessions), 4 sec (5 sessions), 5 sec (8 sessions), 6 sec (7 sessions), and 9 sec. For the other pair (Rat 88/89), the progression was as follows : 3 sec (7 sessions), 4 sec (3 sessions), 5 sec (8 sessions), 6 sec (7 sessions), 7 sec (5 sessions) and 9 sec. Thus the final baseline schedule for the master rats was tand FR1 DRO 9sec. The baseline schedule was maintained for 46 sessions. The rats were then transferred to a VT schedule which was matched for both frequency and temporal distribution of reinforcers which obtained during sessions 43 - 45 of the baseline. This condition was maintained for 15 sessions. Both pairs were then returned to the baseline schedules. For the Rat 83/81

pair this was for 14 sessions at which stage the experiment was terminated. For the other pair the experiment was repeated. They were returned to baseline for a further 47 sessions. They were then exposed to a VT schedule (called VT2) for 13 sessions. The VT schedule in this case was based upon the rate and temporal distribution of reinforcement which obtained during the last 3 sessions of the previous baseline phase. Finally they were returned to baseline for 7 sessions.

Behaviours monitored by the event recorders were lever press responses and durations and tray entry responses and durations. In addition reinforcer deliveries were also recorded and there was also a timer pulse present (1 per sec). The rats were run on 5 days per week and session duration was normally 30 min.

8.3. Results

Faulty tape timers occasionally delivered double reinforcers during the following VT sessions. Rat 81 - sessions 1, 2, 4, 5, 8, 10 and 12; Rat 83 - session 1; Rat 89 - session 4, 5, and 8 during exposure to the first VT schedule and sessions 7, 8 and 9 during the second exposure to the VT schedule.

Mean rate of responding for each rat during the last 5 sessions of each schedule condition is shown in figure 8.1. It can be seen that responding was all but eliminated during the VT

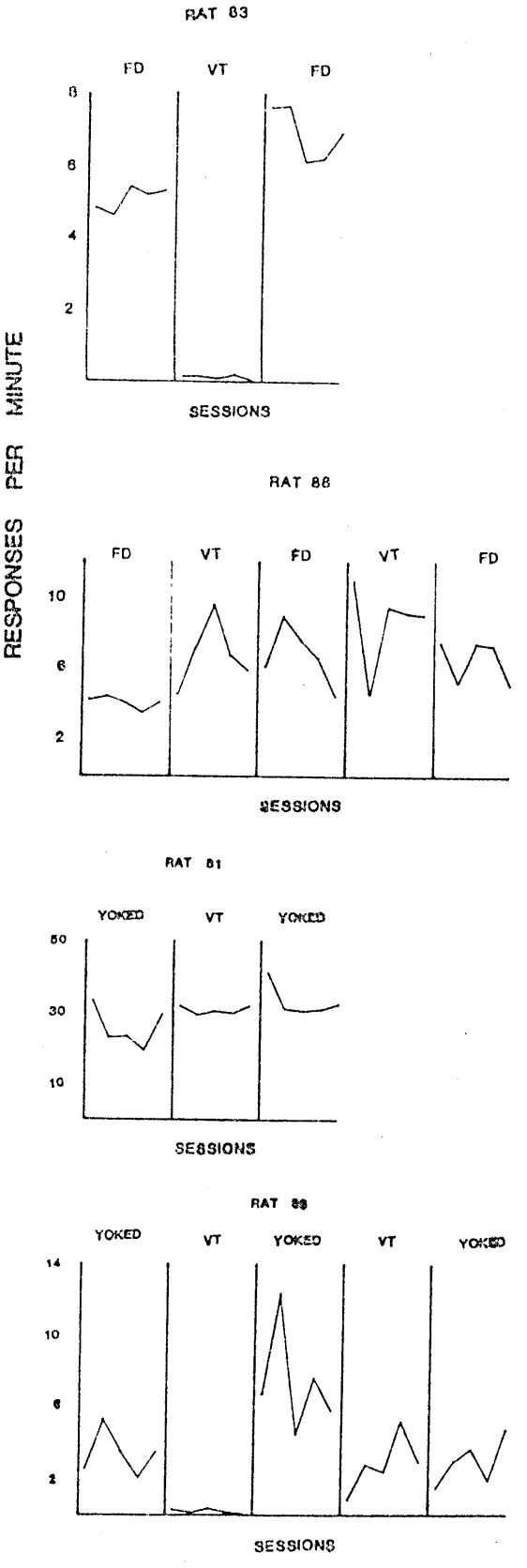


Fig. 8.1. Mean rate of responding during the last 5 sessions of each schedule condition. Schedule indicators are explained in the text.

condition for both Rats 83 and 89, while Rats 81 and 88 show response rate increases relative to the prior baseline condition. In no case was it possible to recover baseline response rate. Although it could be argued that 14 sessions was insufficient for the Rat 83/81 pair, it seems unlikely that the 47 sessions given to the other pair of rats would be subject to the same criticism. The failure to recover baseline rates of responding is not an atypical result (Experiment I: Lachter et al, 1971). For those rats exposed to the VT schedule for a second time, response rate was at least as high or even higher than one of the baseline determinations.

Normalized rates of responding during each VT session are shown in figure 8.2. Rates of responding were normalized with respect to the mean response rate which obtained during those sessions which were used for constructing the VT tapes. A normalized rate of less than 1 indicates response decrement. On the first determination it can be seen that apart from Rat 89, all animals showed a transient increase in response rate (see experiment III). After the second session of VT reinforcement, Rat 83's response rate drops dramatically. For the other two rats, however, the increase in response rate over baseline is maintained, Rat 81 only dropping below the mean baseline rate on one VT session. During that session there were a large number of double reinforcers (19 out of 120 reinforcers dispensed). The increase in rate observed during the VT sessions was significant when tested by the Sign Test (Siegel, 1956) for

both Rats 81 and 88 ($p<.01$). For the second determination, rate of responding is again well maintained for Rat 88. There were three instances in which rate of responding during the VT sessions was below the mean baseline rate; the 10 out of 13 sessions above baseline fails to reach an acceptable level of significance ($p=.092$). For Rat 89, rate of responding during the VT sessions is above the baseline for the first 6 sessions. On the seventh session, however, double reinforcers began to occur. Such episodes were repeated over the next two sessions. Double reinforcers took a somewhat different form during this part of the experiment. Normally, the second reinforcer was dispensed within one second of the first when double reinforcers occurred. In this case, however, there was a delay of about 2 to 3 seconds between the reinforcers (note that the minimum IRI was 9 sec). It could be argued that such an apparatus malfunction would have a more deleterious effect on response emission probability than the former kind of apparatus breakdown, because it is more probable that the rat would have moved away from the tray in the latter case (see also Shimp, 1978). Once the double reinforcers were discontinued, however, response rate began to recover. Relative and absolute response rate differences between the two VT determinations (the first 13 sessions of each) were tested by the Wilcoxon matched-pairs signed-ranks test (Seigel, 1956). These reveal that Rat 88's performance do not differ ($T = 22$, $T = -26.5$, $N = 13$, for the relative and absolute response rates respectively) while Rat 89 shows stronger resistance to response-independent reinforcement on

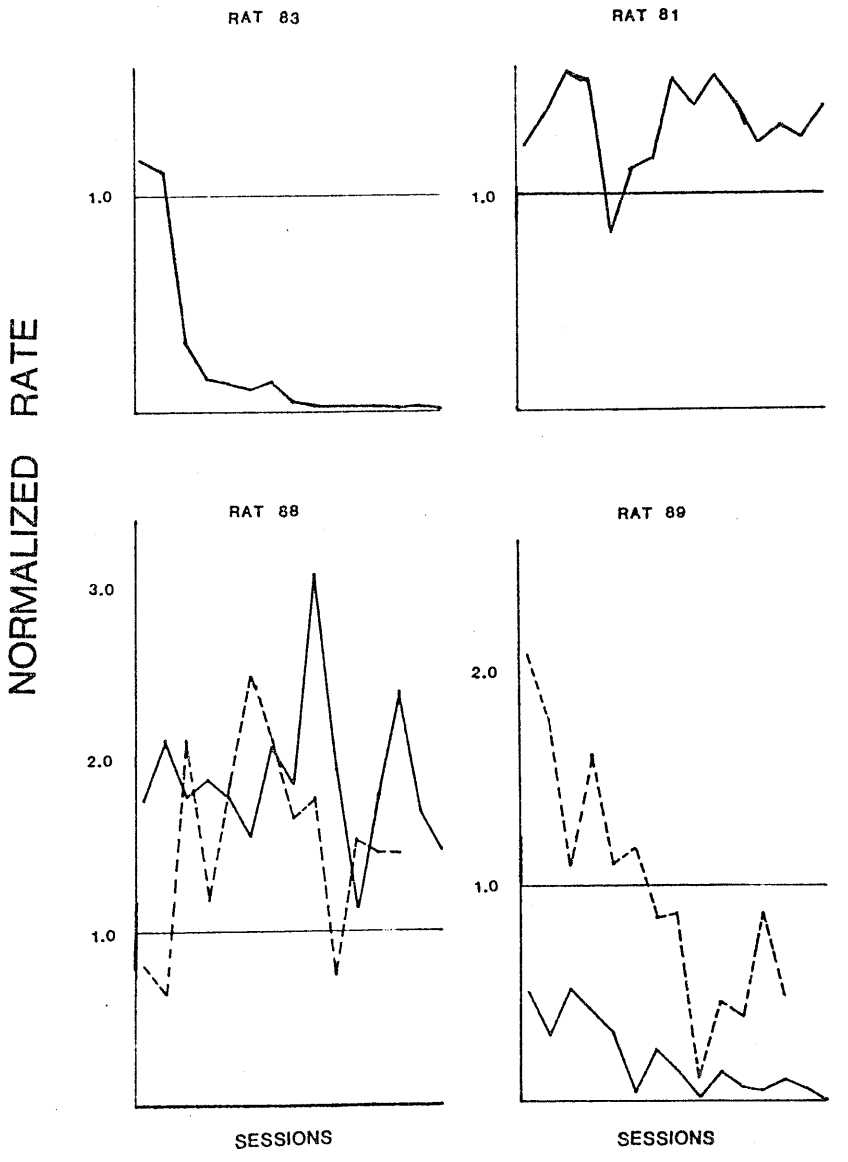
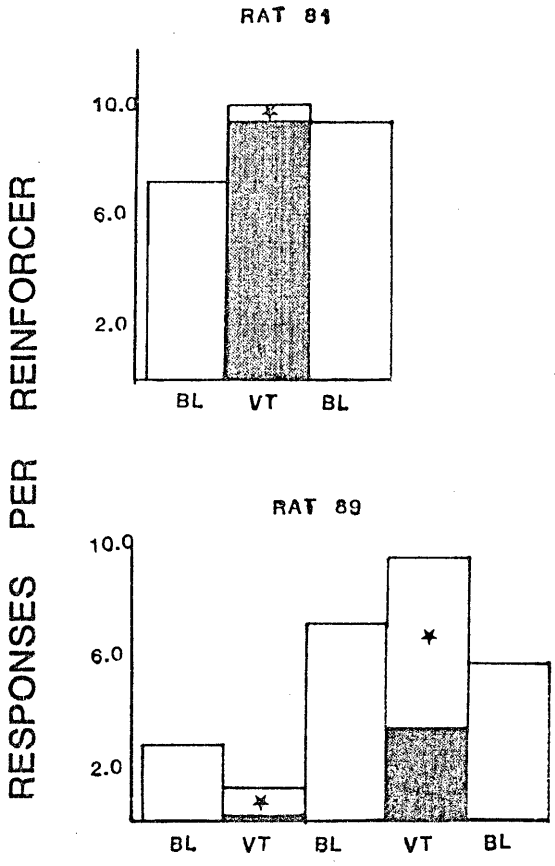


Fig. 8.2. Normalized rate of responding during each variable-time session. The horizontal line represents the mean rate of responding during the previous baseline schedule. Solid lines represent the first variable-time determination, dashed lines represent the second variable-time determination.

the second exposure to the VT schedule ($T = 0$, $N = 13$, $p < .01$ in both cases). These data confirm those found in experiment I, and conflict with those reported by Catania and Keller (1981).

Response per reinforcer during the last 3 sessions of each schedule condition for each rat are shown in figure 8.3. The starred portion represents the ratio when IRIs without a response are excluded. It can be seen that the most efficient responder was Rat 83 while the least efficient was Rat 81. For those rats which showed response decrement, this index of performance during the VT schedule generally dropped, even when IRIs without a response were excluded. Reference to figure 8.2. reveals that the least efficient responders showed the strongest resistance to response-independent reinforcement. This finding confirms the data reported by Davis et al (1973), but conflicts with that reported in experiments III and IV. This index is only an imperfect predictor of resistance to response-independent reinforcement, however. For example, Rat 88's second baseline performance was less efficient than his first baseline performance, yet the VT performances do not differ.

Henton and Iversen (1978) have shown that there is an inverse relationship between the proportion of reinforcers contiguous with 'other behaviour' and lever press probability during both delay of reinforcement and response-independent reinforcement schedules. A measure based on the one they used was implemented here. In this



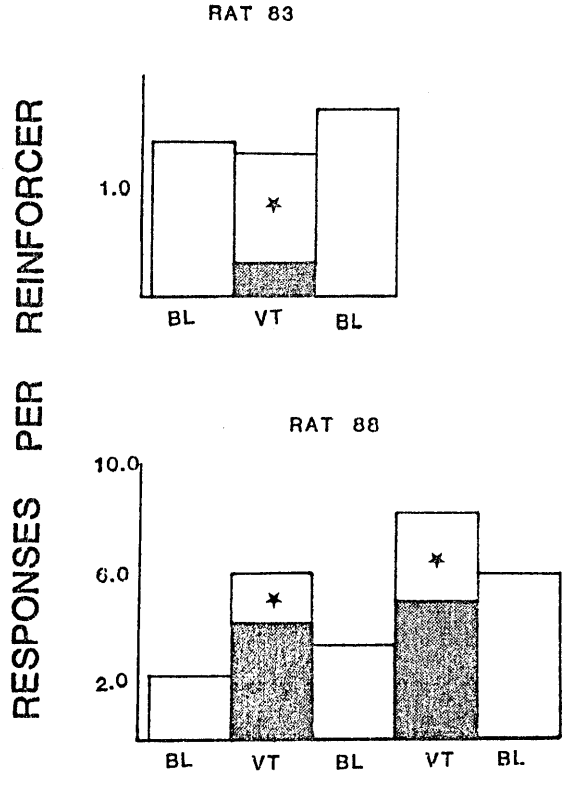


Fig. 8.3.

Responses per reinforcer during the last 3 sessions of each experimental phase. Starred portions exclude IRIs without a response.

BL = Baseline

VT = Variable-time

case, the proportion of reinforcers contiguous with a lever press during VT sessions was correlated with response rate obtained in the respective session. Contiguity between a response and a reinforcer was operationally defined as a temporal interval of less than 1 sec (Henton and Iversen, 1978). Correlations were not calculated for either Rat 83 or Rat 89 under the first VT determination because each experienced very few response-reinforcer contiguities (Rat 83 10 out of 1662 reinforcer deliveries; Rat 89 4 out of 524 reinforcer deliveries). The results are presented in Table 8.1.

Table 8.1.

Spearman rank-difference correlations between proportion of reinforcers contiguous with a lever press and response rate during the VT conditions.

	VT1	VT2
Rat 81	0.43[1]	-
Rat 88	0.74[2]	0.81[2,3]
Rat 89	-	0.79[2]

1 = Not statistically significant 2 = $p<.01$

3 = Based on 12 sessions, one event recording was lost.

It can be seen that the majority of the correlations are highly significant. To the extent that the 1 sec criterion is somewhat arbitrary (Catania and Keller, 1981 used

0.33sec), the type of measure used here is only an approximation of the temporal relationships which existed between responding and reinforcement. The choice of a different criterion quite clearly would have produced a different set of correlations, while the measurement of actual delays might have provided a more sensitive assessment. It was not possible, however, to resolve time intervals of less than 1 sec (the data reported in Table 8.1 were based upon measurements taken from event recordings - vide infra). Using that time interval as a base, the distributions of obtained delays of reinforcement for Rats 81, 88 and 89 are shown in figure 8.4a-c (Catania and Keller, 1981). The data from two VT sessions are shown for each rat, as well as those from one baseline session for Rats 81 and 89 (Rat 88 is excluded because the response-reinforcer delays were always 9 sec in duration). The VT sessions were selected on the basis of rate of responding, viz., where possible sessions in which rate of responding either exceeded that or was less than that emitted during the prior baseline phase were chosen. The numbers appended to the baseline label relate to the number of sessions before the VT schedule was introduced, while the number appended to the VT label represents the particular VT session. The VT sessions represented for Rat 88 are from the first determination, while those for Rat 89 are from the second. The mean rate of responding during the baseline for Rat 88 was 3.98 responses per minute. Figures 8.4a-c reveal that there is an inverse relationship between rate of responding and obtained delay of reinforcement. For Rat 81

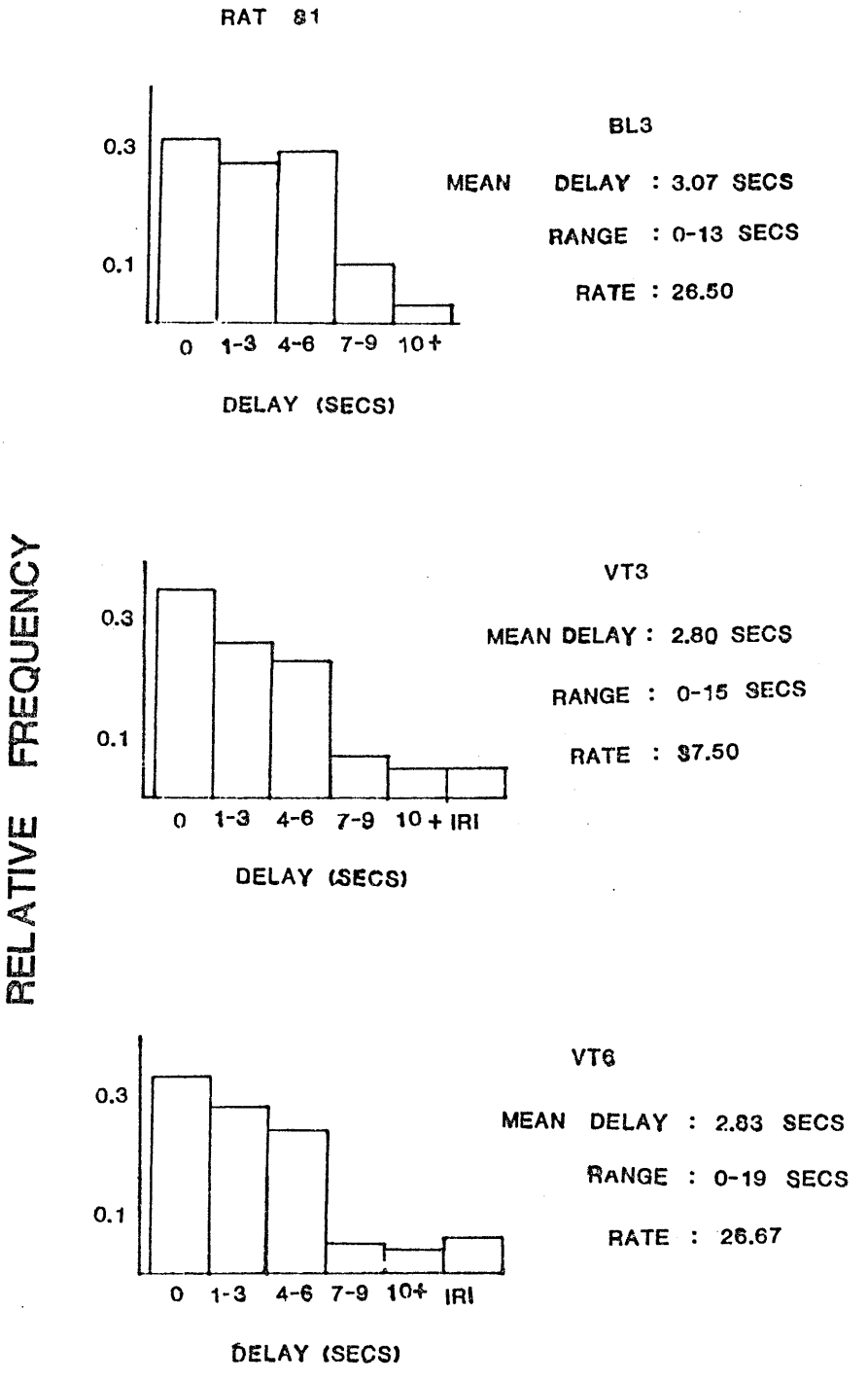


Fig. 8.4a. Relative frequency of occurrence of different delay durations during a selected baseline and variable-time sessions. BL = baseline; VT = variable-time; IRI = interreinforcement intervals without a response. See text for details.

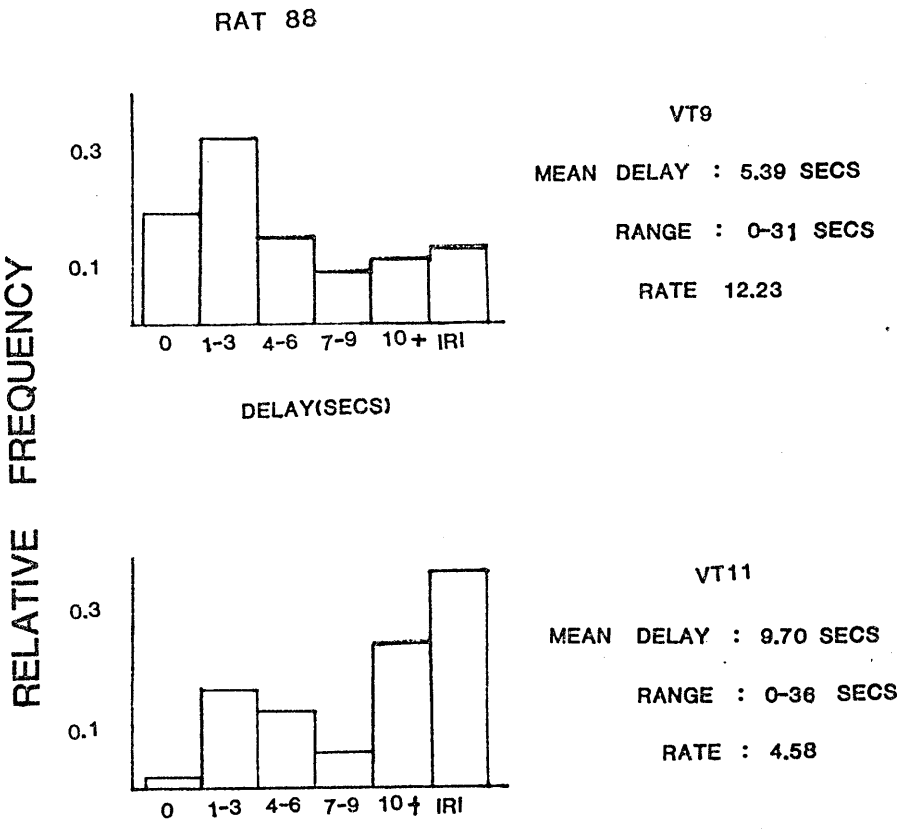


Fig. 8.4b. Relative frequency of occurrence of different delay durations during selected variable-time sessions. VT = variable-time; IRI = interreinforcement intervals without a response. See text for details.

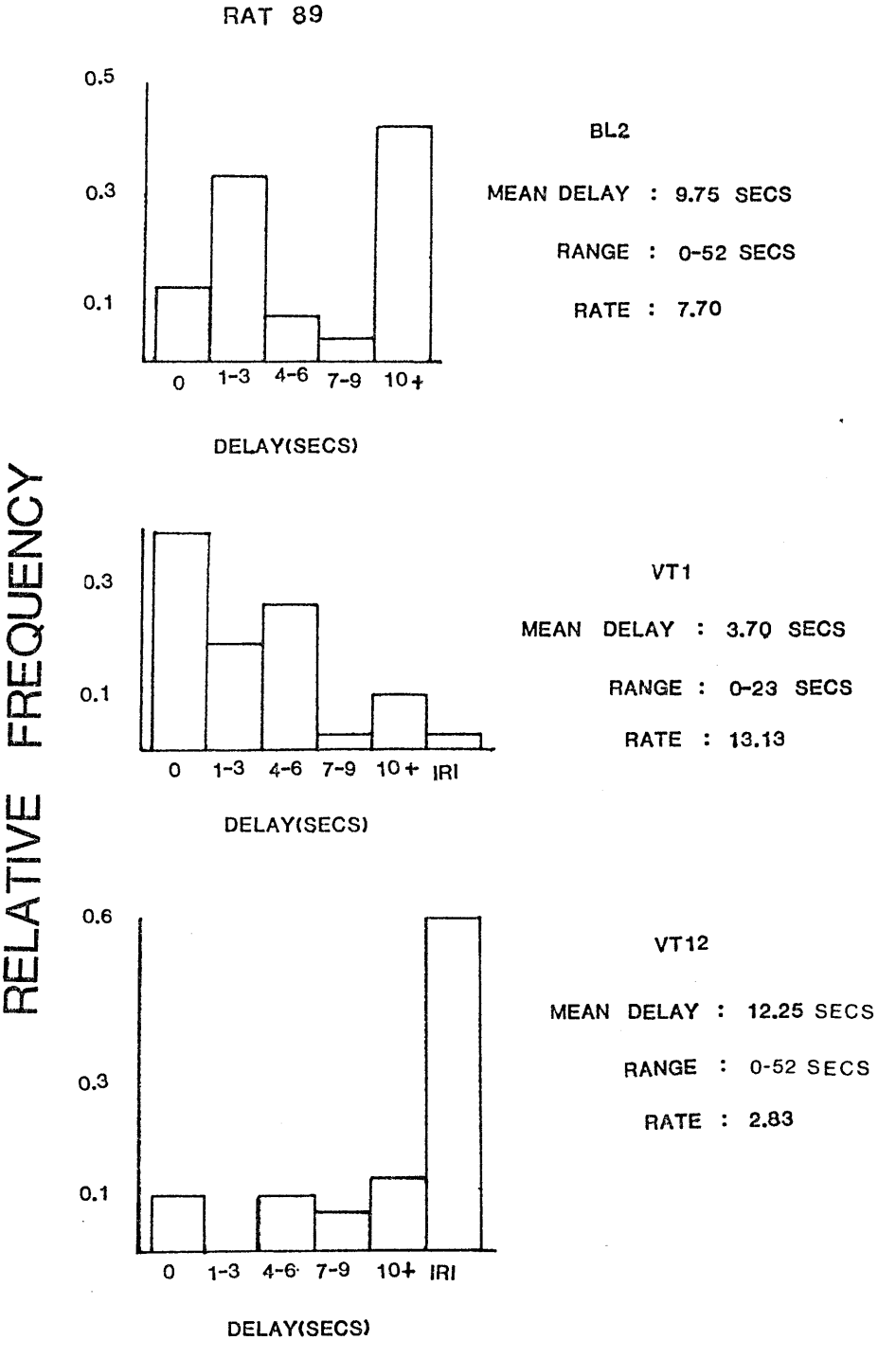


Fig. 8.4c. Relative frequency of occurrence of different delay durations a selected baseline and variable-time sessions. BL = baseline; VT = variable-time; IRI = interreinforcement intervals without a response. See text for details.

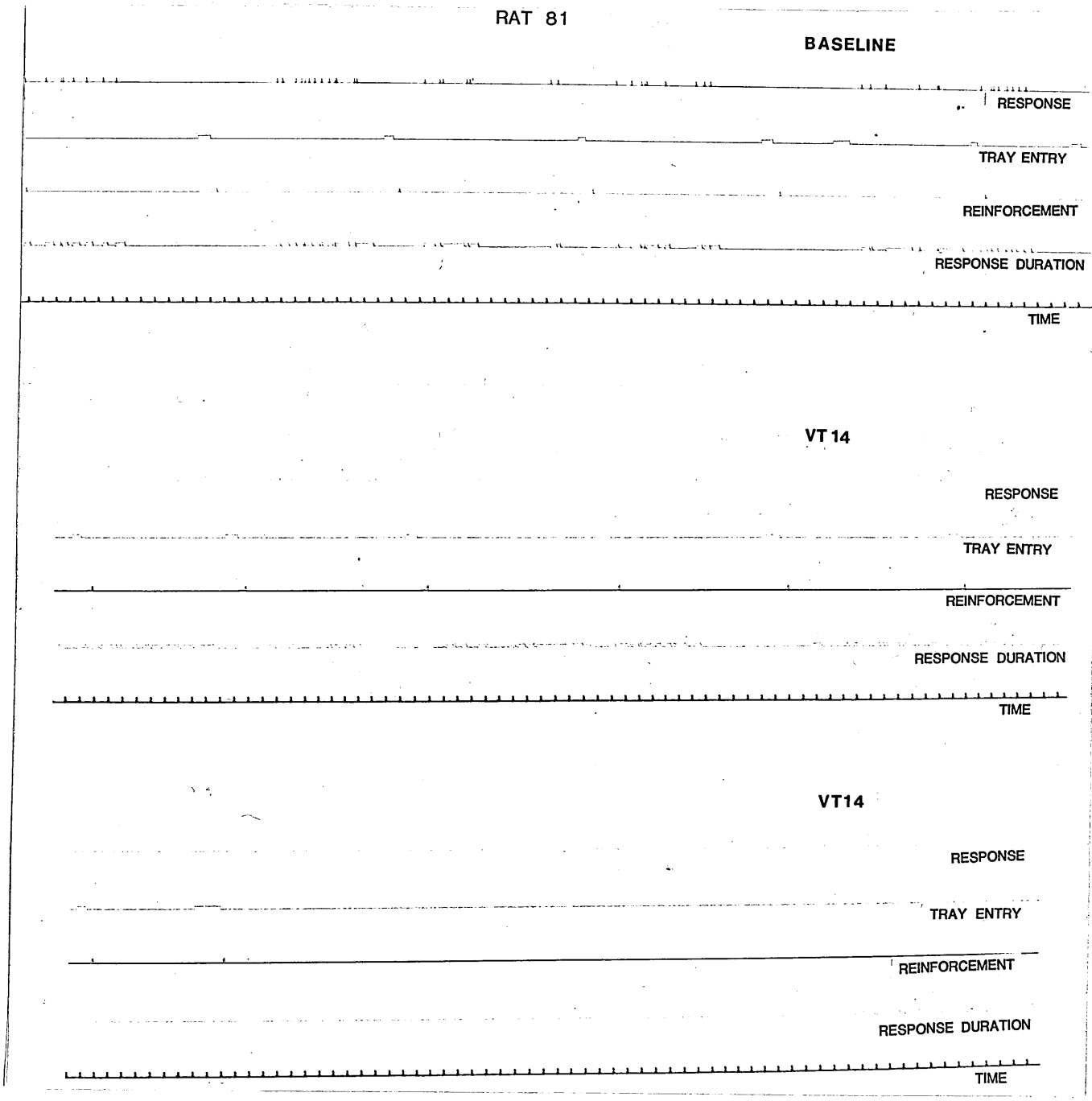
(fig. 8.4a) it can be seen that increases in rate of responding are associated with a higher relative frequency of very short reinforcement delays. In the lower rate session, there is a slight increase in the relative frequency of IRIs without a response. These trends are much more obvious in the data shown for Rat 89 (fig. 8.4c). The data from Rat 88 show a marked shift in the delays of reinforcement towards the longer durations in the lower rate session. There is also a noticeable increase in the relative frequency of IRIs without a response. Although only two VT sessions are shown here, the data confirm that reported in experiment IV in showing an inverse relation between delay of reinforcement and response rate. Therefore, the same kind of relationship which exists between these variables when reinforcers are response dependent is also evident when reinforcers are presented independently of responding (e.g., Weil, 1984; Williams, 1976).

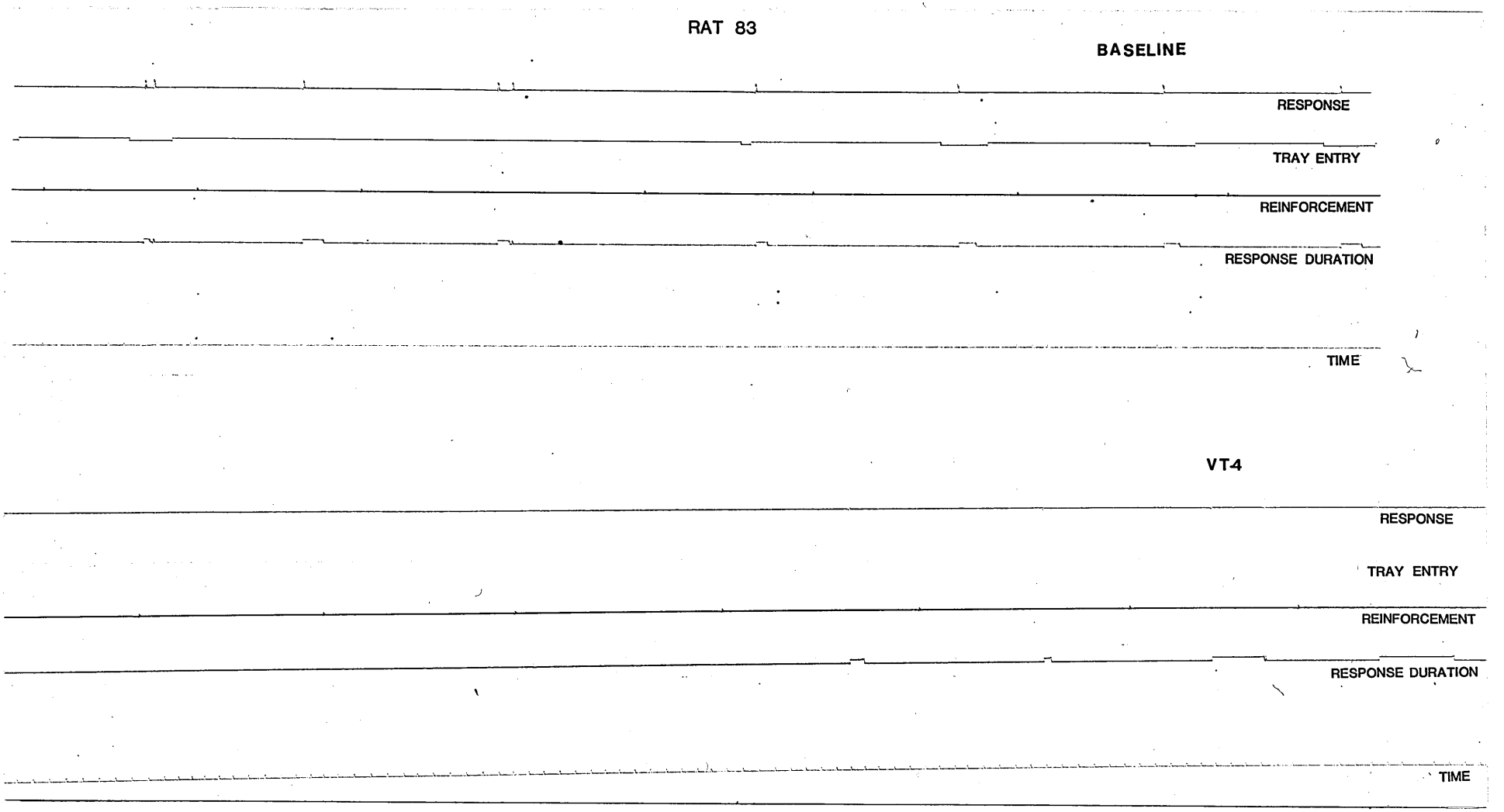
The relationship between IRIs without a response and response rate was assessed by Spearman rank-difference correlations. These were as follows: Rat 81: -0.17; Rat 83: -0.90; Rat 88: -0.40 for VT1 and -0.62 for VT2; Rat 89: -0.95 for VT1 and -0.91 for VT2. All are statistically significant at the 5% level or better (Rats 83 and 89) besides those for Rat 81 and Rat 88 for the first determination under the VT schedule. The reason for the lack of significance for Rat 81 was the low frequency of occurrence of IRIs without a response (94 cases out of 1550

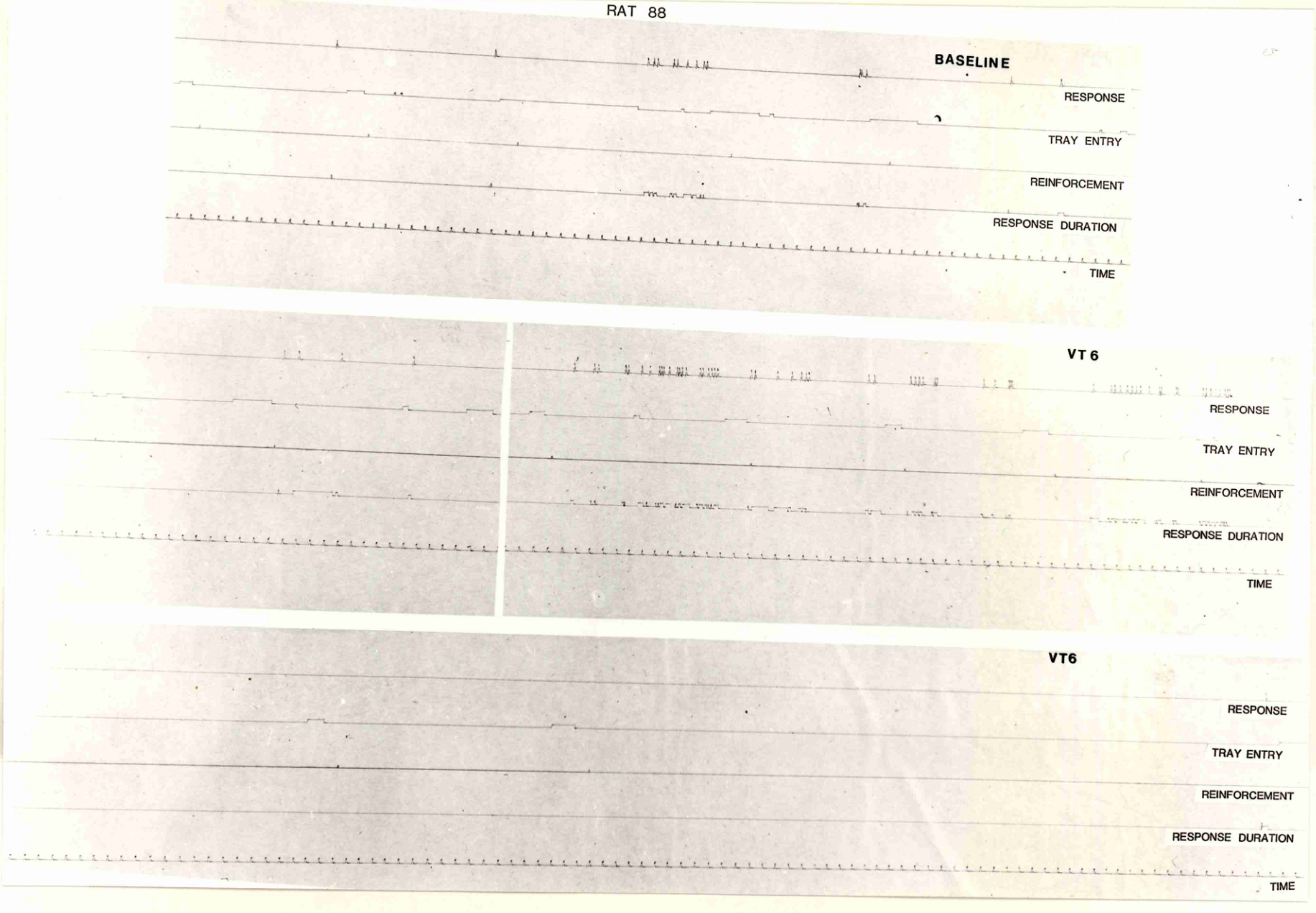
IRIs). Such was not the case for Rat 88, however. This variable was possibly over-shadowed by the delays of reinforcement.

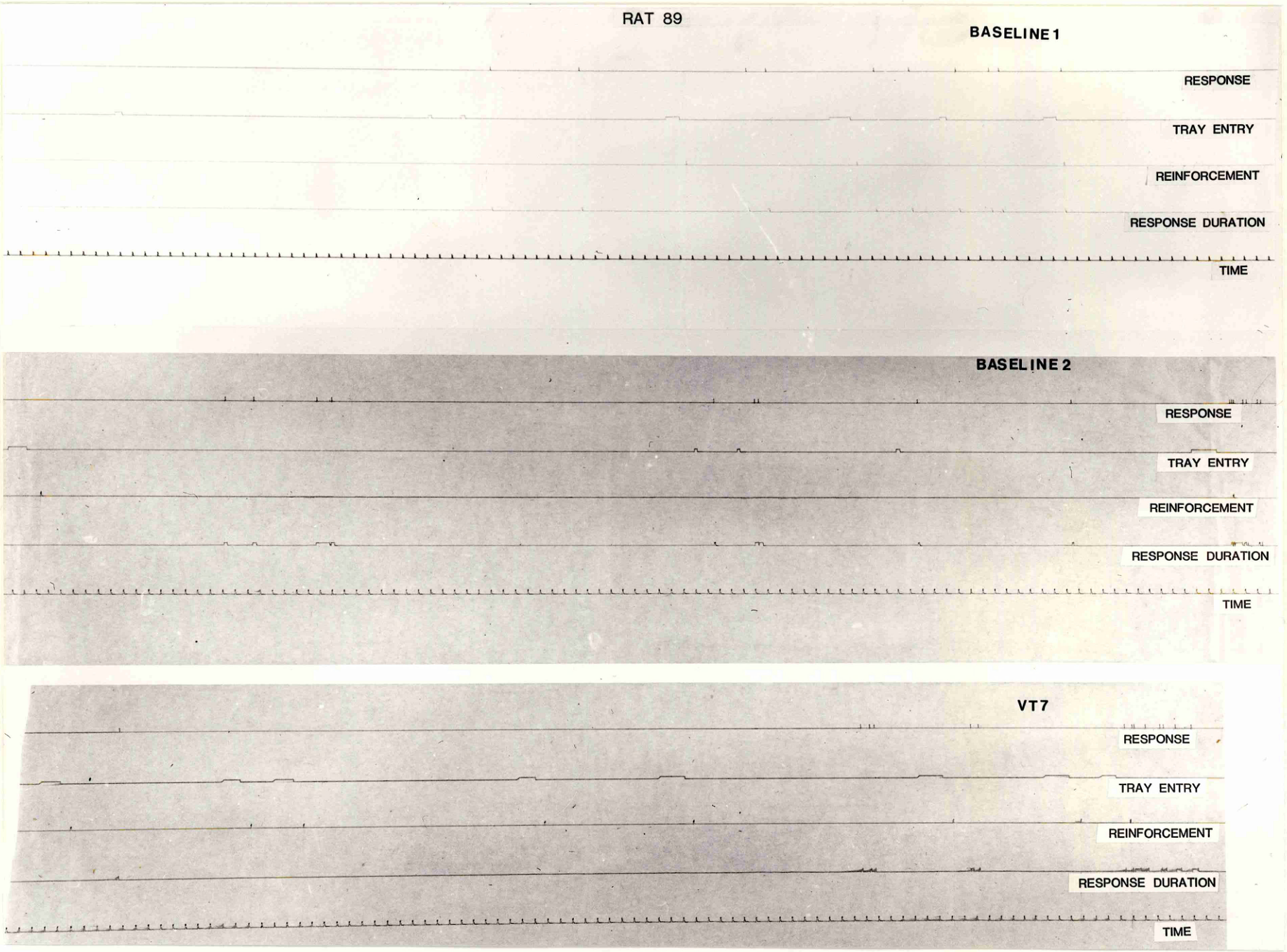
Selected event recordings are shown in figures 8.5a-d. It can be seen that Rat 81 responds reasonably evenly throughout the records shown. There are cases present where the animal maintains responding even after a reinforcer has been delivered (i.e., he does not enter the tray immediately). A similar sort of result has been reported by Catania and Keller (1981). An example of an IRI without a response is also shown. In this example, which was typical for this rat, it followed a reasonably long delay of reinforcement (Henton and Iversen, 1978). The record for Rat 83 shows a marked stereotyped form of responding during the baseline. This took the form of the rat emitting a lever press and then entering the tray until the reinforcer was delivered. This pattern of behaviour is maintained at the beginning of the VT session shown, but eventually the lever press yields to remaining in the tray. Tray entry responding therefore replaced lever pressing. It is some interest to note that <u>frequency</u> of entering the tray actually decreased during the VT sessions relative to the prior baseline. In terms of time allocation, however, the event recordings showed an increase over baseline (Pear and Rector, 1979). Reference to fig. 8.5c reveals that the pattern of responding for Rat 88 during the baseline can be best described as being erratic, with bursts of responding present. The VT session illustrates the bursts of

Figs. 8.5a, b, c, and d. Event recordings from baseline and variable-time sessions for each rat. Numbers appended to the baseline label refer to the determination. Numbers appended to the VT label refer to a particular session under the VT schedule. The data for Rat 88 are from the second determination. The data from the variable-time session for Rat 89 are from the second determination. The records run from right to left.


RAT 81
BASELINE
RESPONSE
TRAY ENTRY
REINFORCEMENT
RESPONSE DURATION
TIME
VT 14
RESPONSE
TRAY ENTRY
REINFORCEMENT
RESPONSE DURATION
TIME
VT14
RESPONSE
TRAY ENTRY
REINFORCEMENT
RESPONSE DURATION
TIME


RAT 83
BASELINE
RESPONSE
TRAY ENTRY
REINFORCEMENT
RESPONSE DURATION
TIME
VT4
RESPONSE
TRAY ENTRY
REINFORCEMENT
RESPONSE DURATION
TIME


RAT 88
BASELINE
RESPONSE
TRAY ENTRY
REINFORCEMENT
RESPONSE DURATION
TIME
VT 6
RESPONSE
TRAY ENTRY
REINFORCEMENT
RESPONSE DURATION
TIME
VT6
RESPONSE
TRAY ENTRY
REINFORCEMENT
RESPONSE DURATION
TIME


RAT 89
BASELINE 1
RESPONSE
TRAY ENTRY
REINFORCEMENT
RESPONSE DURATION
TIME
BASELINE 2
RESPONSE
TRAY ENTRY
REINFORCEMENT
RESPONSE DURATION
TIME
VT7
RESPONSE
TRAY ENTRY
REINFORCEMENT
RESPONSE DURATION
TIME

responding once more as well as periods in which pausing is present. Two examples of an IRI without a response are shown. In the first case (left hand side middle record), the IRI without a response is preceded by a response-reinforcer contiguity. In the second case (bottom record), it is preceded by a long reinforcement delay. The second case supports Henton and Iversen's (1978) data, while the former case does not. Instances of the latter kind (i.e., second) were the norm, while those of the former (i.e., first) were rare. It is noticeable from the first part of the VT session shown that response-reinforcer contiguities were normally followed by a short PRP. The data for Rat 89 illustrate baseline sessions from both determinations. It can be seen that this rat responded slowly, with notable pauses between responses. During the second baseline determination, however, there was an example of a response burst. The VT session chosen is that in which the double reinforcers were dispensed. It can be seen that they contacted behaviours other than lever pressing.

8.4. Discussion

The results from this experiment once more disconfirm expectations from correlation theory. Two of the four rats responded at a level which was either equal to or exceeded that observed during the prior baseline response-dependent condition. Of the other two, lever pressing was replaced by tray entry responding in one rat, while the other acquired behaviours which were not automatically recorded. There was no evidence to suggest that variably delaying a reinforcer

resulted in stronger resistance to response-independent reinforcement relative to programming a delay of fixed duration. Further evidence against the correlation view can be found in the data which emerged from the rats that were exposed to a VT schedule on two occasions. Catania and Keller (1981) had found that there was a positive relationship between speed of response decrement under a VT schedule and the number of exposures to VT reinforcement. They argued that such a result supports an analysis of behaviour in terms of discriminating between response-reinforcer dependence and independence. Statistical analysis of the data here, however, revealed that there was either no difference between the two determinations or that performance was stronger during the second determination. These findings confirm data from the second pilot experiment and from experiment I. Finally, the presence of cyclicities in the data (see especially Rat 88) also poses problems for the correlation view.

Contiguity theory seems to fare better than correlation theory. It is clear that response rate during VT is influenced by the proportion of reinforcers contiguous with a lever press. Further, the data shown in fig. 8.4a-c emphasizes the importance of the relationship between delay of reinforcement and response rate. When these data are added to the correlations between the proportion of IRIs without a response and the event recordings there is an impressive array of evidence in favour of a response competition view (e.g., Boakes and Halliday, 1975; Henton

and Iversen, 1978). These are other data, however, which provide some problems for a strict contiguity theory. Consider, for example, the event recordings from Rat 88's performance. An example was shown there in which a response-reinforcer contiguity did not lead to an increase in the probability of responding. This was not an isolated case. Similar examples were found in Rat 89's performance on first being exposed to the VT schedule. Although the number of cases in which a response-reinforcer contiguity was followed by an IRI with a response far outnumber the cases in which it was not, negative instances do arise. Examination of Rat 88's event record of VT session 6 seems to reveal that lever press probability will be increased after a response-reinforcer contiguity when that response is part of a burst of responding. It is noticeable that in all of the cases in which there was strong resistance to response-independent reinforcement in this experiment, part of the response topography involved bursts of responding. This is particularly relevant for Rat 89, in which the event record from the first baseline determination showed no bursting, while there was some evidence of it during the second determination. Note also that there was no evidence of bursts of lever pressing during the baseline for Rat 83. It could be argued that this rat emitted 'bursts' of tray entering behaviours, which was the behaviour which increased in duration during the VT sessions. The argument being proposed here is that response patterning is probably much more important than single response-reinforcer contiguities (Hawkes and Shimp, 1975). Although congiguity theorists

stress the importance of the interaction between behaviours (e.g. Henton and Iversen, 1978; Schoenfeld and Farmer, 1970), they do not provide a measure in terms of which such patterns may be described. The IRT measure may well be the metric required (Shimp, 1975). Certainly, the results from experiment IV indicated its usefulness in this context. A more persuasive case might be made, however, if a baseline schedule which did not selectively reinforce a specific IRT were used and this level of analysis still provided a sound explanation of the data (Marr, 1979; Peele, Casey and Silberberg, 1984; Zeiler, 1977a). This possibility is examined in the next experiment.

CHAPTER 9 EXPERIMENT VI: TRANSITION FROM AN UNSIGNALLED VARIABLE DELAY OF REINFORCEMENT SCHEDULE AND AN IMMEDIATE REINFORCEMENT SCHEDULE TO A VT SCHEDULE: A MOLECULAR ANALYSIS.

9.1. Introduction

The results from experiments III, IV and V demonstrated the utility of a molecular level of analysis in the context of response-independent reinforcement. Two major findings emerged. First, response rate during the VT schedule was closely (and inversely) related to both obtained delays of reinforcement and the proportion of IRIs without a response. These correlational analyses, although not causal, appear to suggest that the cyclicities observed during the VT schedules may be a function of these variables. Second, although individual response-reinforcer contiguities may have dramatic effects on the probability of response emission (Henton and Iversen, 1978), their effectiveness may be mediated by the overall pattern of responding (experiment V). One kind of response pattern analysis is that in terms of IRTs. The results from experiment IV indicated that the IRT distributions appeared to change lawfully with response rate (see also Davis et al, 1973), and, further there was a positive relation between emitted and reinforced IRT distributions.

IRT theory has been criticized on the grounds that although the IRT measure changes lawfully when specified IRTs are selectively reinforced, the measure may not be a fundamental

dimension of behaviour when the IRT duration is not part of the schedule contingencies, i.e., the measure may lack generality (Marr, 1979; Zeiler, 1977a). In experiment IV, a DRL schedule was used as the baseline condition, thus it might be objected that the IRT measure only had heuristic value in that experiment because IRTs of a specified duration were shaped and maintained during the baseline. A more persuasive case might be made for IRT theory if schedules which do not have this characteristic as a defining property were used as baseline conditions, but the same functional relations still remained. The present experiment addresses this possibility.

Specifically, two groups of rats were exposed to one of the response-dependent reinforcement schedules which were used in the second pilot experiment prior to being transferred to VT schedules matched in terms of overall rate and temporal distribution of reinforcement to the previous response-dependent reinforcement condition. This between-groups design permitted the use of more powerful statistical techniques than had previously been employed. In addition, the experiment was run by computer. This made the measurement of both IRT durations and delays of reinforcement during the VT schedule possible. It also permitted the writer to assess the validity of one of the hypotheses proposed by Henton and Iversen (1978), viz., since response-reinforcer contiguities are proposed to increase the probability of response emission, it is reasonable to deduce that PRP durations should be shorter

after a response-reinforcer contiguity than they will be after response-reinforcer delays. In line with the data already reported, it is expected that response persistence will be stronger after exposure to delayed reinforcement than after immediate reinforcement. Further, there will be an inverse relationship between response rate during VT and both obtained delays of reinforcement and the proportion of IRIs without a response. Finally, to the extent that IRT theory has generality beyond IRT-schedules, IRT distributions should be related to rates of responding such that a decrease in response rate will be associated with a shift to the right in the shape of the IRT distribution, further, there will be a positive relationship between overall and reinforced IRT distributions.

9.2. Method

Subjects

Six male Lister hooded rats which were about 6 months of age at the beginning of the experiment. They were maintained at 85% of their free-feeding weights. The animals were individually housed and water was available ad lib in their home cages. All were experimentally naive.

Apparatus

Two two-lever Campden Instruments rodent test chambers which have already been described (see experiment I).

All experimental events were controlled by a Data Nova General Computer. Electronic counters also recorded the

number of responses emitted by the rats as well as the number of reinforcers delivered.

Procedure

The rats were allowed to explore the experimental chamber during the first session. They were then shaped to lever press by the method of successive approximations. The rats were then exposed to an ascending series of VR schedules, the terminal parameter of which was VR7. The rats were then exposed to the experimental schedules. The experimental schedules were programmed in the same manner as those used in the second pilot experiment which was reported in Chapter 3. They involved the use of a recycling time period (T) which was always 5 sec in this experiment, and probability of reinforcement (p). As in the second pilot experiment, reinforcement could be either delayed or immediate. The rats were split into two groups, i.e., there were 3 pairs of rats. One of each pair was exposed to the delay schedule (Group D rats) while the other was exposed to the immediate reinforcement schedule (Group I rats). The schedule parameters were T = 5sec, p = 0.8 which was subsequently reduced over 5 sessions to 0.5. After 15 sessions, however, rate of responding from the Group D rats was very low so they were transferred to the immediate reinforcement schedule for a further 13 sessions. In these the schedule parameters were T = 5sec, p = 0.4. The rats were then split into two squads once more. Rate of responding within pairs was matched as closely as possible. Group D was comprised of Rats 95, 96 and 98; Group I was comprised of Rats 97, 99

and 100. The Group D rats were exposed to the delay schedule with parameters of T = 5sec, p = 0.8. The p value was decreased over 4 sessions to 0.2. A similar reduction took place for the Group I rats. These values were retained for the rest of the baseline schedules. Thus in the Ferster and Skinner (1957) schedule classification the delay schedule was a tand FR1 VT25 sec schedule while the immediate schedule was a tand FR1 VI25 sec schedule. The baseline schedule remained in effect for 44 sessions. The rats were then transferred to VT schedules matched in terms of overall reinforcement frequency and temporal distribution of reinforcement to the final 6 sessions of the preceding baseline schedule. The rats were exposed to the VT schedule for 27 sessions. There was a 10 day break, however, between sessions 17 and 18. Finally, the animals were returned to their respective baseline schedules for 10 sessions. The rats were run on 5 days per week and session duration was usually 30 min.

9.3. Results

Rat 95, a member of the delayed reinforcement group, was dropped from the experiment because of a succession of apparatus malfunctions. These took the form of the delivery of double reinforcers on some VT sessions, while on others, the tape timer jammed. Apparatus malfunctions of these kinds took place on 5 of the first 6 VT sessions as well as during later sessions. Similar sorts of apparatus malfunctions occurred for all rats, besides Rat 97, at some

time during the VT sessions. Detailed apparatus breakdowns were as follows.

Rat 96 - occasional double reinforcers on VT sessions 2, 4, 5, 20, 21, 22, 23 and 24. In addition this rat was removed from the chamber on session 4 after 3 min because the pellet dispenser jammed open. The rat was returned to the chamber after about 10 min.

Rat 98 - occasional double reinforcers on VT sessions 5, 18, 20, 21, 23 and 24.

Rat 99 - occasional double reinforcers on VT sessions 5, 10, 14, 15, 16 and 25.

Rat 100 - occasional double reinforcers on VT sessions 2, 21 and 22.

When they occurred, double reinforcers were dispensed about 2 or 3 times per session. The interval between them and the scheduled reinforcer was typically about 0.5 sec.

Responses per minute during the final 6 sessions of the baseline and VT phases are shown in figure 9.1. Generally, the immediate reinforcement schedule induced a higher rate of responding than the delayed reinforcement schedule. The VT schedule was associated with response decrement for all rats relative to the prior baseline phase although the Group D rats' response rates were comparable with those emitted during the second baseline determination. As in the second pilot experiment, baseline response rates were difficult to recover, especially with respect to the delayed reinforcement schedule.

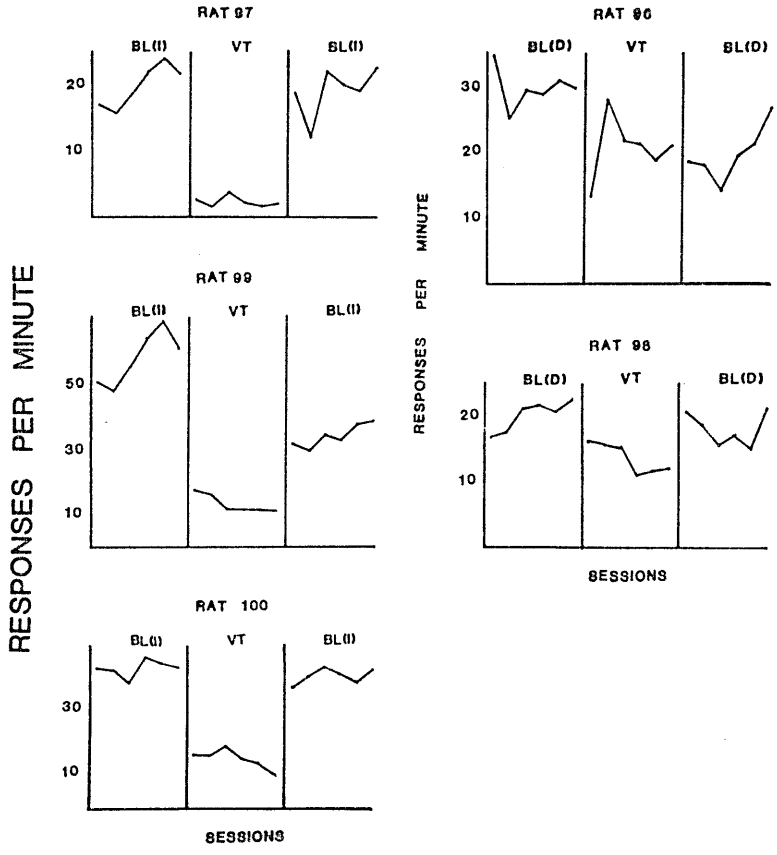


Fig. 9.1. Mean rate of responding during the last 6 sessions of each schedule condition. BL(I) refers to the baseline immediate reinforcement schedule; BL(D) refers to the baseline delayed reinforcement schedule; VT refers to the variable-time schedule.

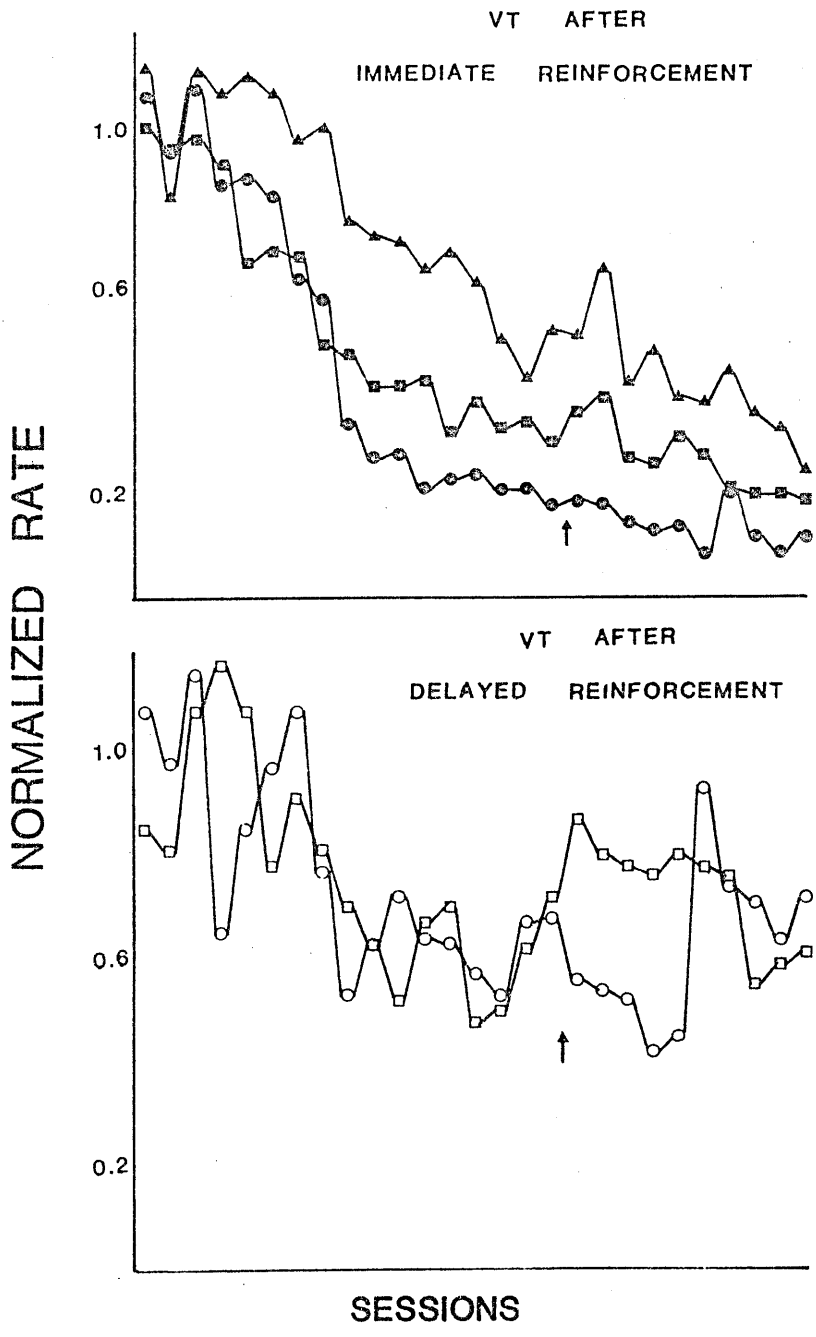


Fig. 9.2. Normalized rate of responding during each VT session. Rat 96 - open circles; Rat 97 - solid circles; Rat 98 - open squares; Rat 99 - solid squares; Rat 100 - solid triangles. The arrow refers to the 10 day break in training.

Normalized rates of responding during each VT session are shown in figure 9.2. The rates were normalized with respect to the mean rate of responding during the final 6 sessions of the preceding baseline condition. It is clear that normalized rate of responding declined for all rats over the VT sessions. The decline, however, appears to be much more severe for the Group I rats. This is the case for both level and trend of decrement. There is some indication that normalized rate of responding stabilized at a higher level for the Group D animals. There also appears to be a strong cyclical trend in this group's data.

The results depicted in figure 9.2 indicate there may be trend present in the data. After log transformation the trends in the normalized rates were approximately linear. A linear regression analysis was carried out for each animal and the resultant slopes were then tested against a zero slope. The results of this analysis, along with the percent of variance accounted for by the slope are presented in table 9.1.

Table 9.1.

Slopes from the least squares linear regression analysis

	Slope	t-value	Significance Level	% Variance
Group D				
Rat 96	-0.0078	-3.12	.01	25
Rat 98	-0.0055	-2.53	.02	17
Group I				
Rat 97	-0.0397	-14.68	.001	89
Rat 99	-0.0253	-17.28	.001	92
Rat 100	-0.0205	-14.52	.001	89

The results of the analysis shown in table 9.1 indicate that there is indeed a trend in the data, and that all of the slopes are significantly different from zero. There is a within-groups consistency. It is clear that the linear trend is a better approximation to the Group I's log normalized data than it is to Group D's data. It would seem then that the trend in the Group I's data can be best described as an exponential decay function; the same conclusion would not be stated with any degree of confidence when considering the data from Group D (c.f. the % variance column in table 9.1). Although these trends were significant no account has been taken of serial dependency. The linear trend was removed from the log normalized rates and autocorrelations were calculated on the residuals. The lag 1 autocorrelations were, with the exception of Rat 100, statistically significant. Of the lag 2 autocorrelations,

that for Rat 97 achieved statistical significance. To compare results of the two groups it was therefore decided to carry out an ANOVA on the log normalized rates from every third session, beginning with session 3. The model used was the unweighted-means solution with repeated measures on the second factor (Winer, 1970, pp375-378). A summary table of the ANOVA is presented in table 9.2.

Table 9.2.

Unweighted-means solution on the log normalized rates from experiment VI

Source of Variation	SS	df	MS	F
Between Subjects				
Groups	3.838	1	3.838	4.36
Subj w Groups	2.639	3	0.88	
Within Subjects				
Sessions	5.117	8	0.64	13.59**
Sessions X Groups	1.704	8	0.213	4.53*
Sessions X Subj w Groups	1.129	24	0.47	

* = $p<.01$; ** = $p<.001$

The groups factor fails to achieve statistical significance. This is probably due to both the small sample size and the relatively slow decrement in responding shown by Rat 100. The significant sessions term confirms the regression analyses of the data that as sessions continue, response rate declines. The interaction term is illustrated in figure 9.3. This shows that as sessions continue the log

normalized rates diverge further with the delayed reniforcement group showing stronger resistance to response-independent reinforcement. The sample sizes, however, preclude any further (post hoc) statistical analyses.

The relationship between mean delay of reinforcement and response rate during the VT sessions was assessed by means of Spearman rank-difference correlations. These were as follows. Rat 96: -0.40; Rat 97: -0.94; Rat 98: -0.81; Rat 99: -0.92; Rat 100: -0.88. All are significant at the 1% level, except for Rat 96 which achieves significance at the 5% level. The same statistic was used to assess the relationship between the proportion of IRIs without a response and response rate during the VT condition. The following correlations emerged. Rat 96: -0.38; Rat 97: -0.90; Rat 98: -0.60; Rat 99: -0.82; and Rat 100: -0.65. The correlations for the Group D rats are significant at the 5% level while those for Group I animals reach the 1% level. The same trends are shown by both of the variables correlated with mean response rate, viz., in all cases the correlations are higher for the Group I animals relative to those in the delayed reinforcement group. It is also noticeable that in every case the correlations involving mean delay of reinforcement are higher than the respective ones between the proportion of IRIs without a response and response rate. This might

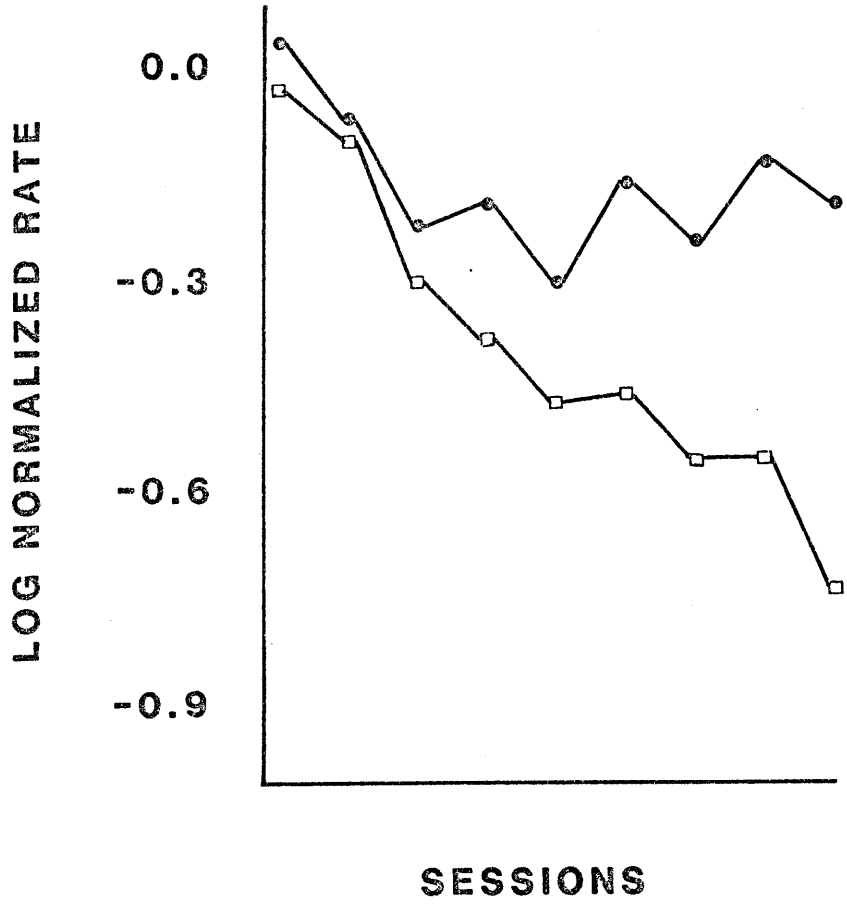


Fig. 9.3. Log normalized rate of responding during every third session for the delayed (solid circles) and immediate reinforcement (open squares) groups.

simply reflect a greater range of values for the former variable relative to the latter or that mean delay of reinforcement is a more fundamental variable. That IRIs without a response play some role in influencing response persistance may be deduced from the data shown in table 9.3. There the mean delays of reinforcement during the last 3 sessions of each schedule condition are shown for the Group D rats. It can be seen that in one case the mean reinforcement delay was in fact shorter during VT relative to the baseline, yet response rate during the VT sessions was lower. The presence of IRIs without a response may have contributed to the lower rate.

Table 9.3.

Mean delay of reinforcement in sec during the last 3 sessions of each experimental phase.

	Baseline	VT	Baseline
Rat 96	5.9	2.8	6.5
Rat 98	3.5	5.9	7.5

The median PRP durations during the last 3 sessions of each phase are shown in table 9.4. Also illustrated is the change during the VT schedule expressed as a proportion of the median of the prior baseline phase. It can be seen that the median PRP value increased for all rats during the VT sessions relative to baseline. Both the absolute duration during VT and relative changes were consistently higher for

the Group I rats relative to the Group D animals. These results indicate that the VT schedule had a greater effect on the behaviour of the animals which were shifted from an immediate reinforcement schedule than on the behaviour of those transferred from a delayed reinforcement schedule. This result supports Schoenfeld et al's (1973) contention that a VT schedule is more likely to disrupt the pattern of responding induced by an immediate reinforcement schedule than one maintained by an unsignalled delay of reinforcement. As in the pilot experiment on which this experiment was based, PRP durations were not necessarily shorter under the immediate reinforcement schedule relative to the delayed reinforcement schedule.

Table 9.4

Median PRP durations in sec during the last 3 sessions of each experimental phase. Proportional change from the prior baseline condition is shown in brackets.

Group(animal)	Baseline	VT	Baseline
I			
Rat 97	8.6	14.4(1.67)	7.9
Rat 99	4.8	12.2(2.54)	10.1
Rat 100	3.7	9.5(2.57)	6.6
D			
Rat 96	5.5	7.5(1.36)	6.5
Rat 98	4.9	6.5(1.33)	5.5

The PRP measure was also used to evaluate one of the hypotheses proposed by Henton and Iversen (1978). As noted in section 9.1, to the extent that shorter PRP durations reflect a higher probability of response emission (on aperiodic schedules) then PRP durations should be shorter after a response-reinforcer contiguity than after a response-reinforcer delay. This was assessed by examining data from the last 3 sessions of the VT phase. A delay was defined as any interval between a response and reinforcer which was greater than 1 sec. Rat 97 was excluded from this analysis because there was no response-reinforcer contiguities during two of the three sessions which were used. The results of this analysis appear in table 9.5. The range of PRP durations is also shown.

Table 9.5.

Mean PRP duration in sec after response-reinforcer contiguities and delays during the last 3 sessions of the VT condition. Range of durations is shown in brackets.

Animal	Contiguous	Delay
	Session 25	
Rat 96	6.3(0.2-23.20) (11)*	9.6(0.2-27.6) (32)
Rat 98	4.5(3.7-5.5) (6)	6.6(2.2-20.9) (38)
Rat 99	15.3(12.6-17.7) (3)	11.4(0.1-34.8) (40)
Rat 100	6.0(0.2-22.4) (13)	7.7(0.1-24.6) (34)
	Session 26	
Rat 96	5.0(0.1-13.50) (12)	8.0(3.4-15.8) (34)
Rat 98	9.7(2.2-32.6) (5)	5.9(2.1-32.6) (45)
Rat 99	10.9(0.2-18.0) (5)	11.9(0.1-25.3) (38)
Rat 100	7.0(4.4-10.2) (8)	10.6(2.0-25.0) (29)
	Session 27	
Rat 96	7.1(0.1-12.8) (17)	7.8(0.1-29.2) (29)
Rat 98	4.7(2.3-8.8) (9)	6.5(0.1-22.2) (39)
Rat 99	14.5(10.6-20.9) (8)	15.2(0.2-31.1) (25)
Rat 100	8.6(0.2-25.3) (8)	9.7(0.1-23.9) (27)

* Number in brackets below the range of PRP durations refers to the number of cases contributing to the means.

The means were subjected to a Sign Test and this revealed that response-reinforcer contiguities were followed by shorter PRPs ($p = .019$), therefore supporting Henton and Iversen (1978). It can be seen, however, that there was a large crossover in the range of PRP durations. It is also apparent that reinforcer delays occurred more frequently than response-reinforcer contiguities; this leads to the possibility that any outliers may have biased the results. Some of the PRP durations were very brief. It is possible that these were parts of a burst of responding (either a continuing one or the beginning of one) (see Catania and Keller, 1981; experiment V).

Overall and reinforced IRT distributions are presented in figures 9.4a-e. The relative frequencies were calculated in the same way as in experiment IV. IRTs were summed over 3 session blocks and relative frequencies based on these sums were then calculated. The baseline determination is based on the final 3 sessions of the first baseline condition. Some of the data were lost so that some of the VT blocks were based on fewer than 3 sessions. The omissions were as follows. Rats 98 and 100 - VT block 3 was based on data from 1 session, while VT blocks 4 and 9 were based upon data from 2 sessions. Rat 97 - VT block 9 was based upon data from two sessions. Note that the bin size varies from rat to rat, but is kept constant across the overall and reinforced distributions. Inspection of figures 9.4b, d and e (i.e., Group I rats) reveals that the baseline schedule

was associated with bipolar distributions with the peaks being at the second bin and the final bin. The VT schedule is associated with a gradual shift to the right, i.e., the relative frequency of long IRTs increases while that for the short IRTs decreases. In all cases, by the end of training, the bin size with the highest relative frequency is the final one. Rat 100's IRT distribution (overall) was becoming unipolar, while a third peak was emerging in Rat 97's distribution by the end of training. The data from the Group D rats were somewhat less systematic. Although both start out with bipolar distributions, a third peak emerged for Rat 98. There was also no systematic increase in long IRTs. The latter measure appears to show a cyclic trend similar to that observed in the response rate data. Comparison of figures 9.4a and c with figure 9.2 shows that recovery in response rate was associated with an increase in the relative frequency of shorter IRTs and a decrease in the relative frequency of long IRTs. The change in the IRT distributions brought about by the VT schedule as well as the PRP duration data shown in table 9.4 indicate that the VT schedules affected response patterning and this effect was stronger in the case of those rats initially exposed to the immediate reinforcement schedule. The reinforced IRT distributions appear to be more irregular than the overall distributions. This was probably a function of the smaller sample size in the former case. Despite that, the general

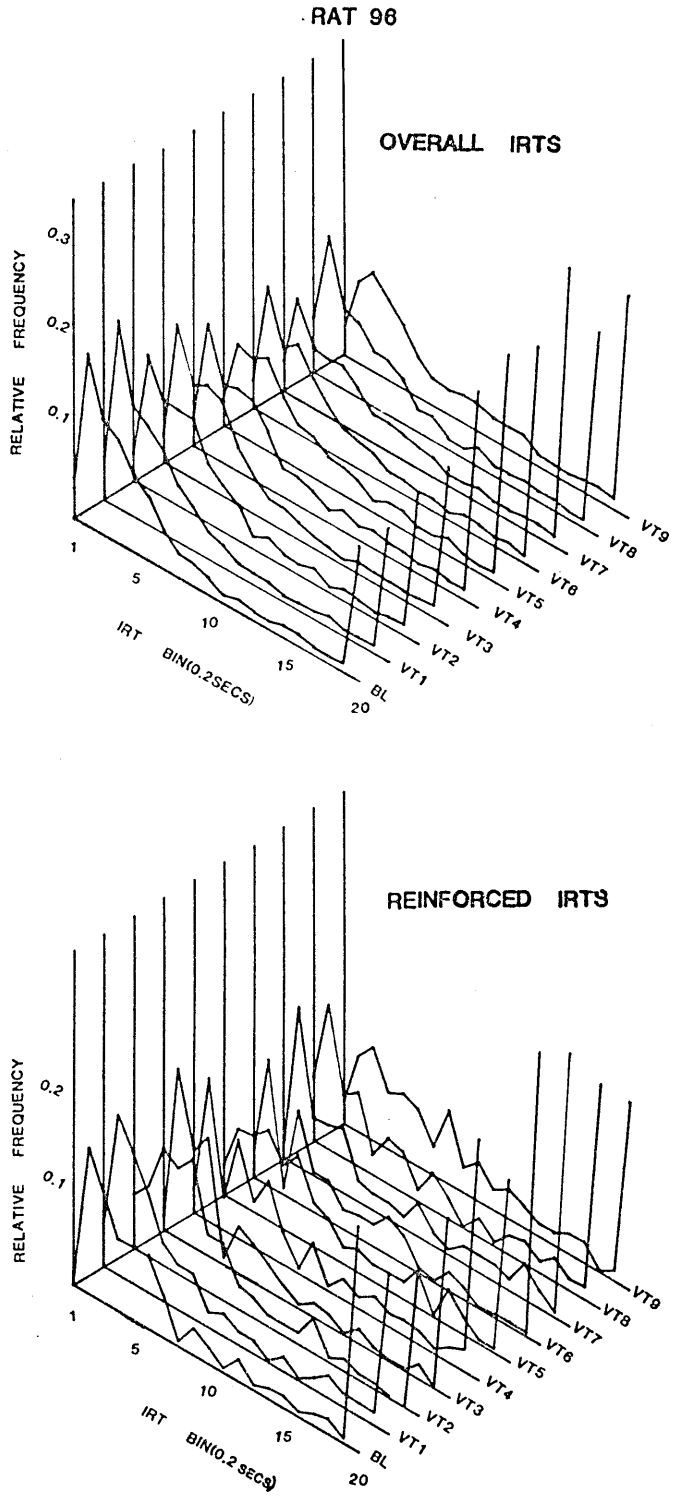


Fig. 9.4a. Overall and reinforced IRT distributions for Rat 96. BL = baseline schedule; VT = Variable-time. See text for details.

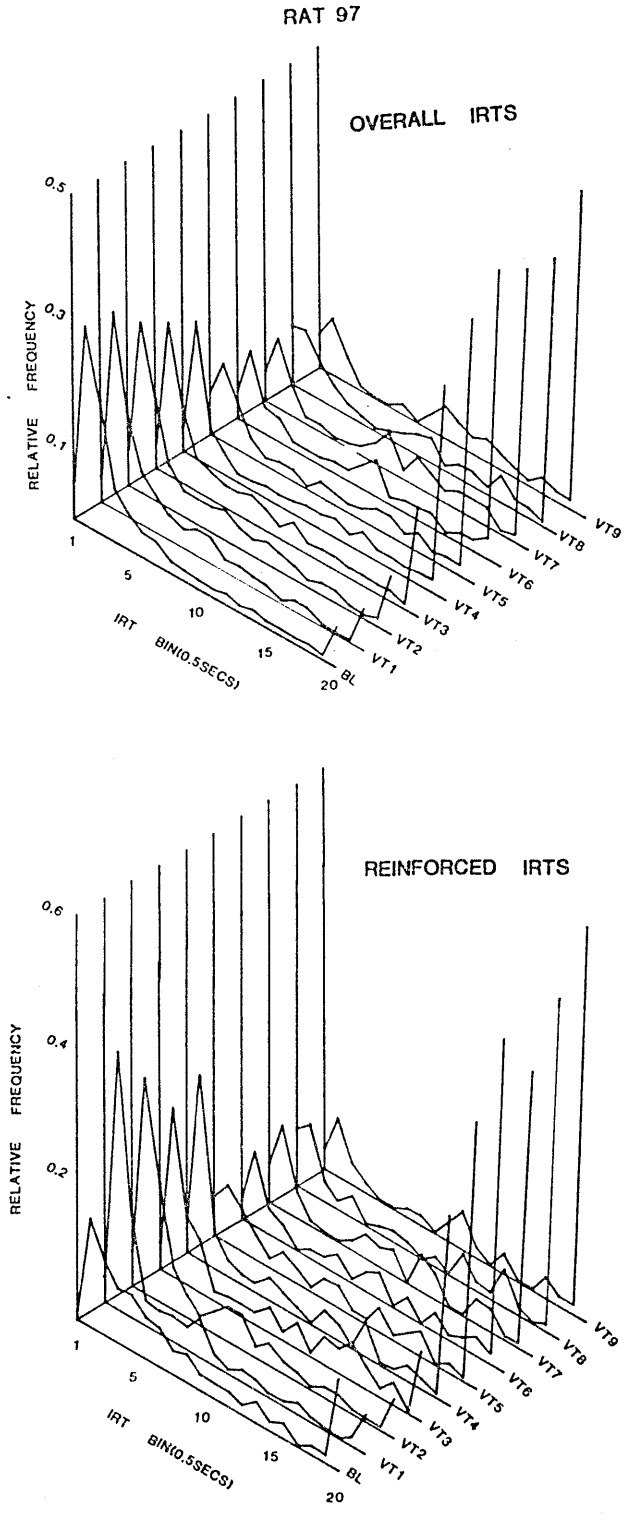


Fig. 9.4b. Overall and reinforced IRT distributions for Rat 97. BL = baseline schedule: VT = Variable-time. See text for details.

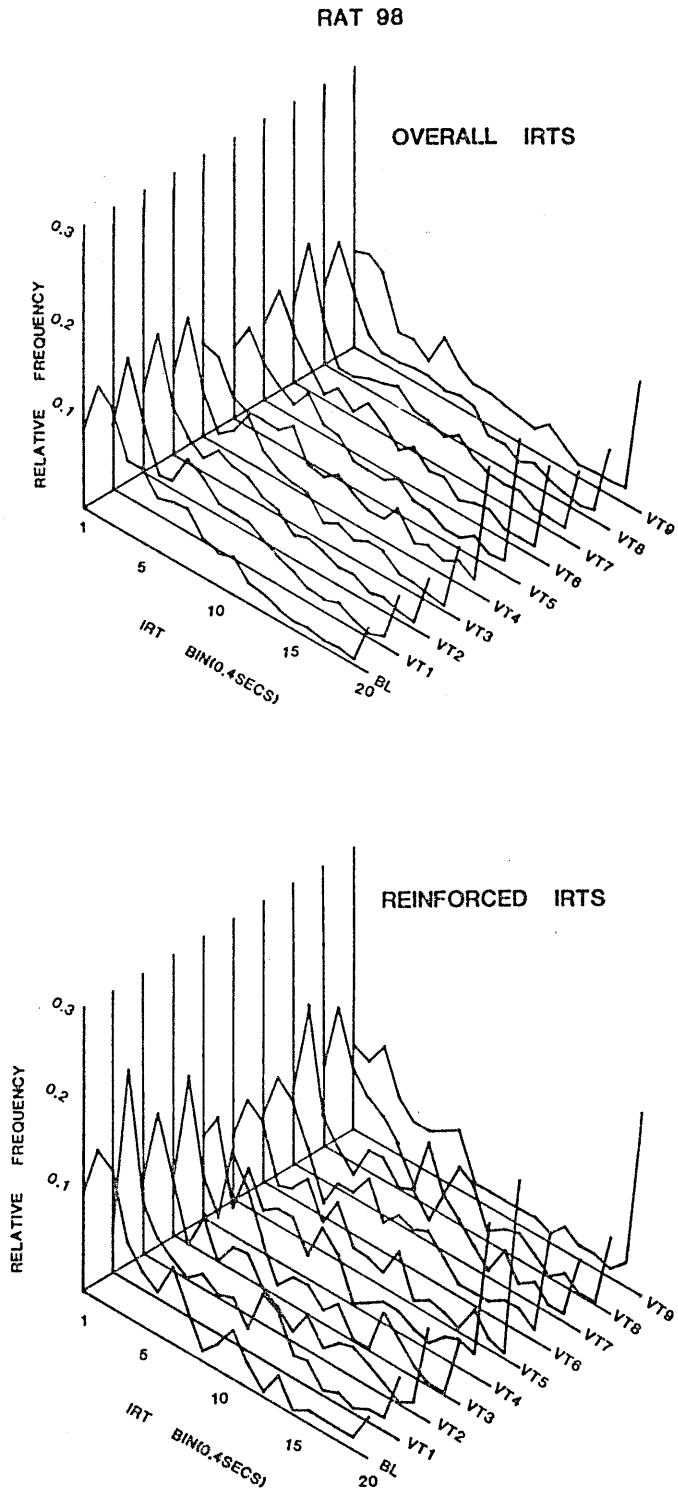


Fig. 9.4c. Overall and reinforced IRT distributions for Rat 98. BL = baseline schedule; VT = Variable-time. See text for details.

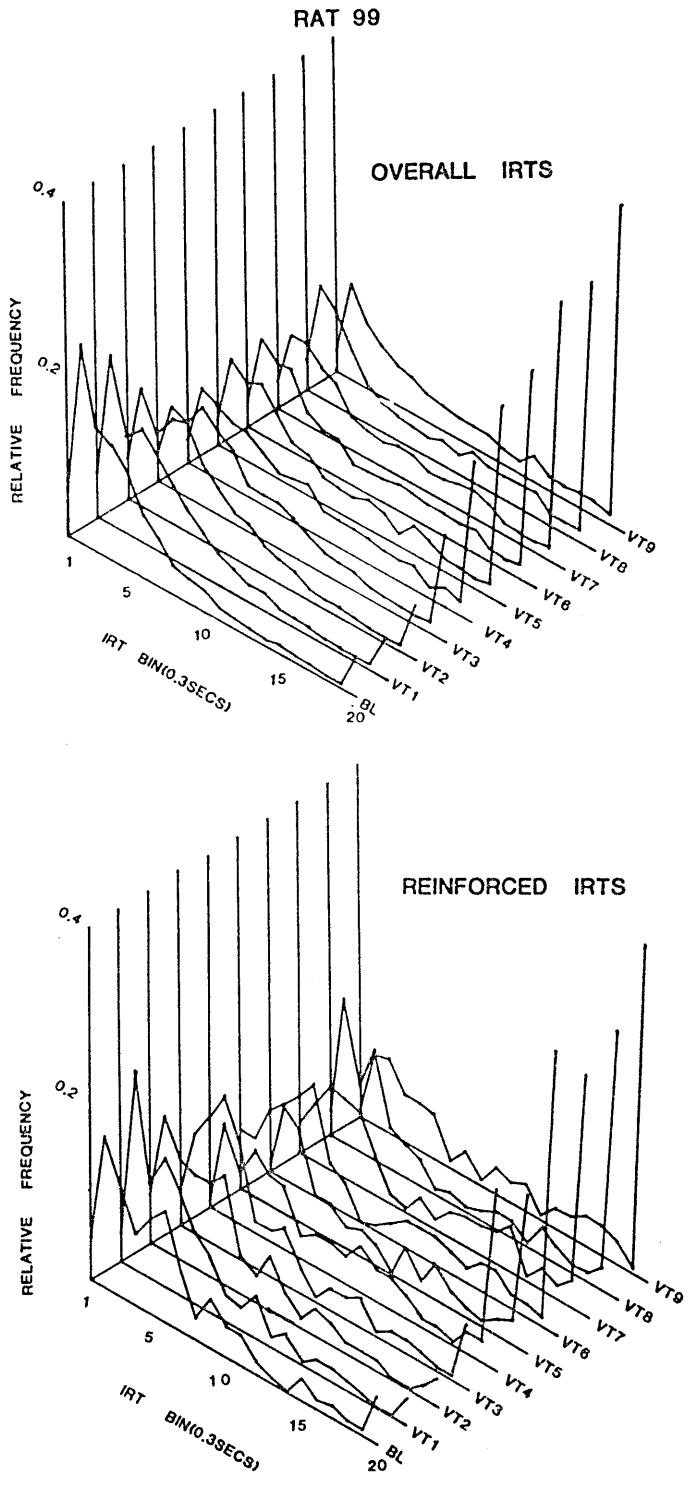


Fig. 9.4d. Overall and reinforced IRT distributions for Rat 99. BL = baseline schedule: VT = Variable-time. See text for details.

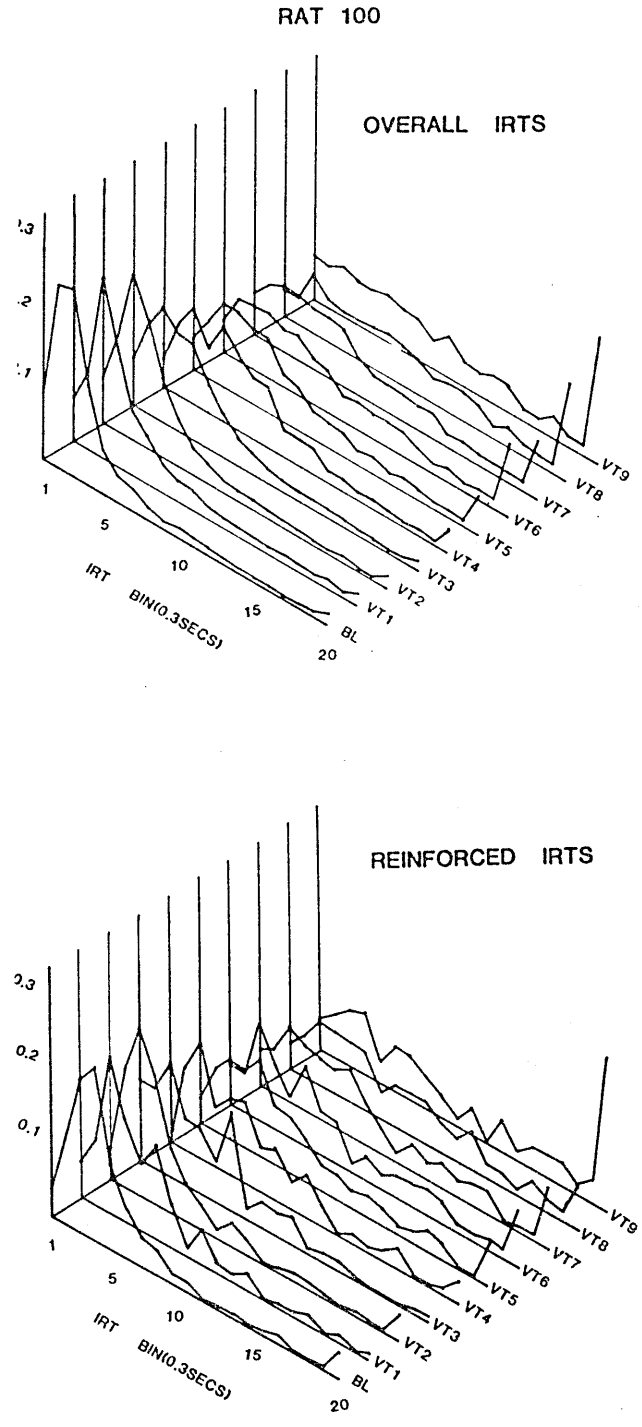


Fig. 9.4e. Overall and reinforced IRT distributions for Rat 100. BL = baseline schedule· VT = Variable-time. See text for details.

shapes of the distributions are similar. The relationship between reinforced and overall IRT distributions was assessed by Spearman rank-difference correlations. The correlations were computed for each VT block as well over all VT sessions. These are shown in table 9.6.

Table 9.6.

Spearman rank-difference correlations between overall and reinforced IRT distributions during the VT condition. Range of correlations is shown in brackets.

Rat 96	0.82**(0.70**-0.95**)	Rat 97	0.80**(0.57* -0.94**)
Rat 98	0.86**(0.72**-0.92**)	Rat 99	0.82**(0.65**-0.96**)
		Rat 100	0.91**(0.72**-0.95**)

* = $p<.005$; ** = $p<.001$

It can be seen that all of the correlations are highly significant; the expectations from IRT theory noted in section 9.1 are confirmed. Considering the strong relationship between changes in response rate and changes in the IRT distributions, it is possible that the changes in the former are mediated by the latter, thus providing support for the molecular approach (Shimp, 1975).

9.4. Discussion

At first glance, the results reported here appear to confirm expectations from correlation theory. Response decrement

was found in both groups, while it occurred more slowly after exposure to the delayed reinforcement relative to the immediate reinforcement schedule (shallower slopes on the linear regression). It is also possible that correlation theory might predict that a VT schedule would have a more disruptive effect on the pattern of behaviour shaped and maintained by an immediate reinforcement schedule than one maintained by a delayed reinforcement schedule. There is evidence, however, which conflicts with the correlation view. First, there are obvious cyclities in the data, and these are much more prominent in Group D's performance during the VT schedule than in the performance of Group I (see figures 9.2 and 9.3). The problem for a correlation theorist here is one of explaining why the lack of a response-reinforcer dependency under the same VT schedule is more difficult to discriminate on some days rather than others. Second, according to correlation theory, molecular events should be 'noisy'. The correlations for all animals between the reinforced and overall IRTs during the VT schedule indicate quite the opposite. Considering that the IRTs were often reinforced at a delay this kind of evidence is even more difficult for molar correlation theory to explain. It would seem that the only way that correlation theory could explain these findings would be to adopt molecular assumptions (see also Thomas, 1981), in which case it loses its defining characteristic.

Contiguity theory has somewhat more success with the data. The significant interaction term in the ANOVA indicates that

stronger resistance to response-independent reinforcement was produced by the delay of reinforcement schedule. Further, the change in PRP durations associated with the VT schedule are in line with this view. Specifically, to the extent that a VT schedule is more similar to an unsignalled variable delay of reinforcement schedule than it is to an immediate reinforcement schedule so it should affect the behaviour of organism less when the transition is from a delayed reinforcement schedule relative to a transfer from an immediate reinforcement schedule. In addition, the relationship between reinforcement delay and response rate provides particularly strong support for a contiguity view. Nevertheless, both groups of rats showed a decline in responding. Why should the delayed reinforcement group show response decrement in this experiment? One reason might be because they experienced increasing delays of reinforcement. Further, the apparatus malfunctions might have added to the effect. A contiguity theorist would argue that the second reinforcer of a double reinforcer episode would be likely to contact ~~R~~. This would strengthen ~~R~~ at the expense of R. As the probability of responding decreases, obtained delays of reinforcement increase and these will further strengthen ~~R~~. The fact that the proportion of IRIs without a response was significantly related to response rate provides some credance for this view.

Other findings, however, are more difficult to explain on the basis of a simple contiguity view. For example, although the mean PRP duration is shorter after a response-

reinforcer contiguity than it is after a response-reinforcer delay, there was a large overlap in the data. Obviously some reinforcement delays were followed by shorter PRPs than followed response-reinforcer contiguities. This type of finding is reminiscent of the one illustrated in experiment V in which it was shown that response-reinforcer contiguities were occasionally followed by IRIs without a response. It may well be the case that response probability is determined by the pattern of responding contiguous with the reinforcer rather than single response-reinforcer occurrences.

In this experiment, the possibility that IRTs would change lawfully under a VT schedule was also examined. There was a close relationship between reinforced and overall IRTs even where there were no programmed contingencies between the behaviour of the organism and reinforcement. Further, there were no specific IRT contingencies in either baseline response-dependent reinforcement schedule. It was clear that as response rate declined over the VT sessions, the relative frequency of long IRTs increased. This was particularly obvious in the data from the Group I rats where response decrement was somewhat more regular. The data presented in this experiment support that reported in Chapter 7 in confirming the IRT measure as a useful metric of response patterning under VT schedules (Shimp, 1975). These results also provide support for the view that the IRT may be a fundamental dimension of behaviour which is dynamically related to reinforcement (Peele et al, 1984;

Shimp, 1975).

The results from experiments IV, V and VI all lend support to the notion that behaviour under VT schedules is probably best examined by employing a molecular level of analysis.

CHAPTER 10 GENERAL DISCUSSION

10.1 Review of experimental data

The general aim underlying the experiments reported in Chapters 4 to 9 was to isolate the controlling variables responsible for response maintenance under VT schedules. The independent variable which was manipulated was the type of reinforcement schedule used as the baseline condition. As the experiments proceeded, the level of analysis became more molecular and the search for the controlling variables began to focus more on events taking place during the VT condition rather than during the baseline. The change in direction from molar to molecular was predicated by the results which emerged.

The experiments can be classified into 3 groups. Comprising the first group are experiments I and II. Experiments III, IV and V form the second group while the third category covers experiment VI.

Experiments I and II addressed the proposal that response maintenance would be superior after training on an unsignalled variable delay of reinforcement schedule relative to training under immediate reinforcement conditions. In addition the response rate prevailing during the baseline phase was also manipulated. The results from experiment I were particularly clear. Response persistence was associated with exposure to a delay of reinforcement schedule during the baseline phase. The VT schedule was

correlated with a marked decrement in response rate after training on an immediate reinforcement schedule. The response rate manipulation had effects which were opposite to those predicted by contiguity theory. Specifically, response persistence tended to be stronger after a response-dependent reinforcement which induced the lower rate of responding. The results from experiment II did not confirm these trends. In this experiment, the baseline schedules were either FR or FR+delay schedules (there was one animal which was exposed to a VI+delay of reinforcement schedule). The FR schedule generally produced superior resistance to response-independent reinforcement than the delay schedule. In terms of rate of responding, the results were somewhat inconsistent. Response rate was directly related to response persistence for those animals exposed to the FR schedule. No such relationship was evident, however, in the delayed reinforcement group's data. Cumulative records revealed that the patterns of behaviour which were emitted by the rats which showed strong response persistence after exposure to the FR schedule were atypical (Ferster and Skinner, 1957). The possibility was entertained that the relationship between response rate during the baseline and resistance to response-independent reinforcement was mediated by the patterns of responding which were induced during the baseline condition. The general implication of these two experiments was that, although a delayed reinforcement schedule could lead to unusually strong resistance to response-independent reinforcement (Schoenfeld et al, 1973), the effect was probably determined by the

pattern of responding which was induced during the baseline and how this pattern interacted with the VT reinforcers.

The next 3 experiments attempted to analyse this possibility. This was achieved by using response-dependent reinforcement schedules in the baseline which demanded the emission of the designated operant and other behaviour in a specified sequence. Specifically, Schoenfeld et al (1973) have argued that response persistence during response-independent reinforcement schedules is stronger after an unsignalled variable delay of reinforcement schedule than after an immediate reinforcement schedule because the former schedule permits both R and $\not R$ to be contiguous with the reinforcer. In experiments III, IV and V the placement of R and $\not R$ was varied while only one response class was allowed to be contiguous with the reinforcer. In the first experiment in this series, the animal was exposed to a tand FR1 DRL10 sec schedule prior to being transferred to a VT schedule i.e., a period of $\not R$ was bounded by R-occurrences. In the second experiment the baseline schedule was a DRL10 sec schedule, while in the third, a tand FR1 DR09 sec schedule constituted the baseline condition (a yoked delay schedule was also present in this experiment). The results which emerged were that first, the immediate reinforcement schedules were associated with stronger resistance to response-independent reinforcement than had heretofore been found. Second, a fixed-delay baseline condition yielded response persistence which was as strong as that induced by a variable delay of reinforcement schedule. Third, rate of

responding was inversely related to obtained delays of reinforcement during the VT phase while it was directly related to the proportion of reinforcers which were contiguous with a response. Fourth, changes in response rate were related to changes in the IRT distributions. Fifth, when they occurred with sufficient variability, the proportion of IRIs without a response was inversely related to response rate during the VT condition. It appeared that response persistence under VT schedules was a function of molecular variables.

The final experiment took these findings a step further. A similar kind of analysis as was used in experiments III - V was carried out on behaviour maintained by schedules which did not demand the emission of specified periods of $\not{R}$, although such behaviour was permitted to occur. In one schedule condition it was allowed to be contiguous with the reinforcer (a delay of reinforcement schedule), while in the other, $\not{R}$ - reinforcer contiguities were not permitted. Despite a series of apparatus malfunctions, the evidence presented showed that the delay of reinforcement schedule led to stronger resistance to response-independent reinforcement relative to the immediate reinforcement schedule. Strong inverse relationships were demonstrated between, on the one hand, response rate during VT with both mean delay of reinforcement and the proportion of IRIs without a response, on the other. Overall and reinforced IRT distributions were closely related. Further, mean PRP duration appeared to be influenced by prior response-

reinforcer contiguities. It was concluded that a molecular level of analysis had been supported.

These are the results which emerged from the experiments. The implications for the two theories which set the occasion for the conduct of the experiments will now be discussed.

10.2. Molar correlation theory and the transition to response-independent reinforcement.

It was pointed out in section 2.6.1.1. that the most difficult set of data for correlation theory to explain was that relating to the superimposition of response-independent reinforcement onto a baseline response-dependent reinforcement schedule (Lattal and Boyer, 1980; Lattal and Bryan, 1976: Zeiler, 1979b). In each of these experiments, there were cases in which superimposition of relatively low rates of free reinforcers increased response rate relative to the baseline condition. According to correlation theory, this kind of superimposition procedure should lead to either response decrement or no change in response rate, depending upon whether the lack of a response-dependency had been discriminated (Rachlin, 1978; Rachlin and Baum, 1972). On the other hand, the data from those experiments in which there is a simple transfer from response-dependent to response-independent reinforcement have generally supported correlation theory in finding response decrement during the second phase (e.g., Boakes, 1973; Lachter, 1971; Rescorla and Skucy, 1969).

Most of the results presented in experiments I to VI disconfirm expectations from correlation theory. There are three major kinds of contradiction.

First, there were cases reported here where response rates were higher during the VT phase relative to baseline determinations. These occurred in experiment I (Rat 4 after VI+delay), experiment III (Rat 13 after tand FR1 DRL) and experiment V (Rat 81 after tand FR1 VT and Rat 88 after tand FR1 DRO). To the extent that response decrement indicates a discrimination of a lack of a response-reinforcer dependency during the VT schedule, a response increment must also indicate a discrimination between the baseline and response-independent phases. It is difficult to see on what basis this discrimination is made - at least in terms of the variables specified by correlation theory. Even if such a discrimination is made, it is difficult to understand why response rate should increase. Even more puzzling are the data from Rats 3 and 4 in experiment I. On the basis of response rates, both of these animals could discriminate between interval and ratio contingencies but could not discriminate between either of these and response-independent reinforcement.

Second, one of the most obvious trends in the data is the presence of cyclicities. The point here is one of explaining why the organism can 'recognise' the lack of a response-reinforcer dependency on some days but not on others when being exposed to the same VT schedule on each

day. There were cases in the experiments reported here where response rates recovered during the VT schedule (see especially Rat 16 experiment IV; Rat 88 experiment V; Rats 96 and 98 experiment VI for particularly clear examples). Williams (1976) has noted that such cyclicities are difficult to understand on the basis of correlation theory because the programmed correlation between response rates and reinforcement rates do not vary under VT schedules (the correlation is always 0).

Third, response rate during the VT schedules was significantly related to variables which are generally considered to be molecular, e.g., delay of reinforcement. Possibly more damaging to correlation theory was the lawful relation which was found to exist between reinforced and overall IRT distributions under a VT schedule (experiment VI).

For these reasons it seems that correlation theory as predictive model of behaviour under VT schedules has not been supported. Given that most of the anomalies noted can be quite adequately explained by a molecular model, it seems that correlation theory would have to make molecular assumptions in order to explain these data (see also Thomas, 1981). This, however, would defeat the whole notion of correlation theory. It is therefore appropriate to conclude that response maintenance during response-independent reinforcement is not determined by the perception of response-reinforcer relations or the lack of them.

10.3. Contiguity theory and response-independent reinforcement.

Contiguity theory as articulated by Schoenfeld and his colleagues proposes that resistance to response-independent reinforcement is determined by 3 variables. These are the degree to which reinforcers are allowed to be contiguous with behaviours other than the designated operant during the baseline phase (Schoenfeld et al, 1973); the rate of responding which prevailed during the baseline response-dependent phase (Schoenfeld and Farmer, 1970); and the rate of reinforcement during both the response-dependent and response-independent phases (Lachter et al, 1971). All of these may interact, although the type of interaction is not specified. Of these variables, the third was held constant across the response-dependent and response-independent phases in the experiments reported here and therefore will not be analysed further. The predictive value of the other two will now be evaluated.

10.3.1. Effect of variation in response rate during the baseline upon resistance to response-independent reinforcement

The logic underlying the idea that response rate during the baseline should affect resistance to response-independent reinforcement is quite straightforward. The higher the rate of responding, the more R occupies the behaviour stream. When free reinforcers are later dispensed it is more likely that they will contact R-occurrences than if the baseline

schedule induces a low rate of responding. This proposal was specifically tested in experiment I where it was found that response persistence during the VT was either unaffected by rate of responding during the baseline or was stronger after exposure to the schedule which was associated with the lower rate of responding. It was also possible to evaluate this view on the basis of a within subjects comparison in experiment V. In that study there was one confirmatory instance. Thus in 6 within subject comparisons, 5 serve to disconfirm the theory.

In table 10.1 a between subject comparison is presented. The baseline rate provided is the median of the last 3 sessions of the baseline preceding transfer to the VT schedule, normalized rate during VT is the median from the last 3 sessions of the VT phase. Comparisons are made across the same phase of the experiment and the delay and immediate reinforcement schedules are kept apart. It can be seen that of the 30 comparisons, only 9 confirm Schoenfeld and Farmer's (1970) conjecture.

Table 10.1

Discrepancy between predicted and observed order of resistance to response-independent reinforcement based upon response rate prevailing during the baseline.

Animal	Schedule	Baseline Rate	Normalized VT Rate	Predicted Order	Observed Order
		Experiment I			
Rat 1	VR	147.44	0.45	1	1
Rat 2	VI	74.21	0.02	2	2
Rat 1	VI	98.03	0.52	2	1
Rat 2	VR	134.90	0.12	1	2
Rat 3	VR delay	86.77	0.83	1	2
Rat 4	VI delay	17.70	2.18	2	1
Rat 3	VI delay	20.93	0.83	2	1
Rat 4	VR delay	75.90	0.80	1	2
		Experiment II			
Rat 1	FR	202.83	0.70	2	1
Rat 2	FR	206.93	0.70	1	1
Rat 3	FR	43.67	0.36	3	3
Rat 4	FR delay	39.50	0.36	2	3
Rat 5	FR delay	30.00	0.67	3	1
Rat 6	FR delay	39.73	0.30	1	4
Rat 7	VI delay	13.47	0.47	4	2
		Experiment III			
Rat 11	FR1 DRL	8.80	0.06	1	3
Rat 12	FR1 DRL	7.97	0.65	3	2
Rat 13	FR1 DRL	8.42	2.32	2	1

Table 10.1 continued

Discrepancy between predicted and observed order of resistance to response-independent reinforcement based upon response rate prevailing during the baseline.

Animal	Schedule	Baseline Rate	Normalized VT Rate	Predicted Order	Observed Order
		Experiment IV			
Rat 14	DRL	6.81	0.05	2	3
Rat 15	DRL	10.40	0.31	1	2
Rat 16	DRL	6.03	1.03	3	1
		Experiment V			
Rat 83	FR1 DRO	5.27	0.02	1	2
Rat 88	FR1 DRO	4.07	1.73	2	1
Rat 81	FR1 VT	26.50	1.26	1	1
Rat 89	FR1 VT	3.50	0.08	2	2
		Experiment VI			
Rat 97	FR1 VI	22.01	0.12	3	3
Rat 99	FR1 VI	63.53	0.20	1	2
Rat 100	FR1 VI	44.73	0.33	2	1
Rat 96	FR1 VT	29.61	0.64	1	1
Rat 98	FR1 VT	21.63	0.59	2	2

The comparisons shown in table 10.1 are confounded with different rates of reinforcement. An examination of that variable, however, produces much the same kind of

conclusion. It is possible that the rate of responding variable will assume greater importance in those situations in which rate of reinforcement is varied across the response-dependent and response-independent phases (Lachter et al, 1971). Nevertheless, where rates of reinforcement are approximately equal across experimental phases, the response rate prevailing under the response-dependent baseline schedule appears to be largely irrelevant with respect to subsequent resistance to response-independent reinforcement.

10.3.2. Type of baseline schedule and resistance to response-independent reinforcement.

Schoenfeld et al (1973) have proposed that an unsignalled variable delay of reinforcement will lead to stronger resistance to response-independent reinforcement relative to an immediate schedule because the former allows both R- and ✗- reinforcer contiguities, while the latter only allows R- reinforcer contiguities. The contingencies which exist in the delay schedule are similar to those that might exist in a VT schedule (contingency is here being used in the sense of Zeiler's (1972) second categorization - see section 1.3.1.3). This prediction was tested in 3 experiments - experiments I, II and VI, while it was partially assessed in experiment V where a variable delay of reinforcement schedule was pitted against a fixed delay schedule (i.e., one in which there are only ✗-reinforcer contiguities). The strongest confirmation for Schoenfeld et al's (1973) view was found in experiment I where there were no cases of

response decrement after the delayed reinforcement schedule, but considerable amounts were obvious after the immediate reinforcement schedule. The data from experiment VI also confirmed Schoenfeld et al's (1973) proposal although the delayed reinforcement group did show a decrement in responding.

The results from experiment II, however, failed to support expectations from Schoenfeld et al's (1973) view.

Table 10.2 illustrates the frequency of occurrence of obtaining response decrement, no change in response rate or response rate increment during VT relative to the prior baseline schedule. Response decrement was assessed by comparing the rate of responding during each VT session with the mean rate of responding during those baseline sessions which were used in the construction of the VT tapes. The comparison was then evaluated by the Sign Test.

Table 10.2.

Frequency of obtaining response rate decrement, no change in response rate or response rate enhancement during VT as a function of baseline schedule.

Schedule	Response Decrement	No Response Decrement	Response Increment
Immediate	14	1	1
Delay	9	3	4

It can be seen that a delayed reinforcement schedule did lead to greater resistance to response-independent reinforcement than did an immediate reinforcement schedule. It is also noticeable, however, that a delayed reinforcement schedule is neither a necessary nor sufficient condition for producing resistance to response-independent reinforcement. Of interest here is the kind of immediate reinforcement schedule which produced response persistence. The cases of a lack of response-decrement were reported in experiments III and IV in which the schedules were tand FR1 DRL and DRL respectively. Both of these schedules are highly constrained (Zeiler, 1979a). The degree of constraint, however, is not necessarily a useful predictor of subsequent response persistence. Zeiler (1979a) has suggested that ratio schedules are more constrained than interval schedules - at least in terms of response requirements. In the experiments reported here, the former did not lead to superior response persistence during the VT condition. Schedule constraint may be important, however, when the nature of the constraint acts to lower response rates. In this sense a delay of reinforcement schedule is similar to the spaced-responding type of schedule. Both lead to a lower rate of responding than the usual interval schedule, although the mechanism is probably different in the two cases (delay schedules would be expected to induce a lower rate relative to a yoked interval schedule because X can be contiguous with the reinforcer; in the case of spaced-response schedules there is a response-cost contingency present if responding does not meet the required criterion).

The most prudent conclusion appears to be that although unsignalled delay of reinforcement schedules as well as immediate reinforcement schedules in which there is a R requirement yield stronger resistance to response-independent reinforcement relative to other immediate reinforcement schedules, the reinforcement of either both R and ~~R~~ or ~~R~~-R sequences during the baseline are not sufficient conditions, however, for producing resistance to response-independent reinforcement. The fact that both kinds of schedules are sometimes followed by response rate decrement during a subsequent VT schedule indicates that the controlling variables of response persistence during VT conditions reside elsewhere.

Before leaving this section it should be noted that some authors have suggested other variables operative during the baseline which may influence response maintenance during a VT schedule. For example, Rescorla and Skucy (1969) have suggested that the discriminative properties developed by the reinforcer during the baseline are a major contributory factor to subsequent resistance to response-independent reinforcement. Further, Davis et al (1973) have suggested a similar role for efficiency of responding during the baseline (at least when DRL schedules are used). There is sufficient disconfirmatory evidence in both the literature (Boakes and Halliday, 1975) and in the results from the present experiments (see experiments I, III and IV) to dismiss both of these factors as being serious candidates

for predicting the degree of response maintenance during VT schedules.

It has been suggested by Henton and Iversen (1978) that the variables controlling the probability of emission of a response during a VT schedule are not to be found in events taking place during the baseline. Rather, they are likely to be events taking place during the VT schedule itself. This possibility is now analysed.

10.4. The maintenance of responding during VT schedules. The controlling variables.

In the experiments reported here response rate during the VT schedule was related to a number of other dependent variables (see Weil, 1984 for a similar strategy in a different context). Specifically, the relationship between response rate and mean delay of reinforcement, proportion of IRIs without a response and the proportion of reinforcers contiguous with reinforcer was assessed by use of correlation techniques.

In the case of the relationship between mean delay of reinforcement and response rate, the correlations were always statistically significant. In the case of proportion of IRIs without a response, most of the correlations were statistically significant while those between response rate and the proportion of reinforcers contiguous with a response also achieved statistical significance (with the exception of Rat 81, experiment V). All of these measures are related

in that they assess the importance of the response-reinforcer interval in maintaining response rate. These relationships all provide substantial support for a contiguity view.

Given that obtained delay of reinforcement, and the other related measures, are important determinants of response maintenance during a VT schedule, how do they exert their effect? Contiguity theorists have proposed the notion of response competition (Henton and Iversen, 1978; Schoenfeld and Farmer, 1970). Underlying this view is the idea that behaviours compete with one another to yield the total behaviour stream. The primary variable affecting their relative frequencies of occurrence is the frequency with which each is contiguous with the reinforcer. According to this view, response decrement usually occurs under a VT schedule, because the reinforcers contact behaviours other than the designated operant. These other behaviours then replace R-occurrences in the behaviour stream. Therefore, both delays of reinforcement and IRIs without a response will have a similar effect - they will strengthen K. Response competition, however, is usually used in a verbal fashion, i.e., authors who make recourse to it rarely demonstrate that decrement in the measured response, e.g., lever pressing, is associated with a concurrent increase in some other behaviour which has been shown to have been contiguous with the reinforcer (Boakes and Halliday, 1975; Lachter et al, 1971; Schoenfeld et al, 1973). The major exception to this trend is the research reported by Henton

and Iversen (1978). It was noted in section 2.5 that they demonstrated that the proportion of reinforcers contiguous with 'other behaviour' was associated with both a decrease in lever pressing and an increase in the relative frequencies of the other behaviours which were in fact contiguous with the reinforcer. In the present experiments, some of the data from experiment V confirm their view. The event records for Rat 83 demonstrate that this rat remained in the food tray during most of the VT session shown. This was the behaviour which was contiguous with the reinforcer.

This sort of theory can easily account for the cyclicities shown in the data. To the extent that response rate is inversely related to delay of reinforcement and obtained reinforcer delays vary from session to session, so it would be expected that response rate would fluctuate accordingly. This was indeed the case. The relationship between mean reinforcement delay and response rate therefore confirms Williams's (1976) speculation concerning the causation of response rate cyclicities in both delayed and response-independent reinforcement schedules.

The response competition view as espoused by Henton and Iversen (1978) is faced with evidence which might appear to be contradictory. First, underlying Henton and Iversen's (1978) theory is the assumption that all behaviours are equally reinforceable. There is evidence to suggest, however, that this is not the case. There are some aspects of grooming for example which do not seem to be modifiable

by food reinforcement - e.g., face washing in rats (Annable and Wearden, 1979). Related to this point is the spatial arrangement of the animal vis-a-vis the lever when food is presented. Both of these factors could influence response maintenance during VT schedules. For example, suppose that a rat experiences a reinforcer delay of the same duration in three instances. In the first, the behaviour which interceded between the response and the reinforcer was standing, facing the wall opposite to the lever. In the second, the interceding behaviour was face washing. Finally, in the third, the rat was facing the lever with the paw about to contact it. The question here is whether all of these behaviours will compete with the measured operant to the same degree. The response competition view of Henton and Iversen (1978) is silent on this sort of problem. Schoenfeld and Farmer (1970), have suggested that purely temporal definitions of behaviour are probably inadequate and have proposed the use of what they call field equations. Presumably, these would take account of the spatial orientation of the animal, but they have yet to be specified (see also Pear et al 1982).

A second problem facing the Henton and Iversen (1978) view is defining exactly what is meant by a contiguity between a response and reinforcer. They have adopted the criterion of any interval which is less than 1 sec. Catania and Keller (1981) have used 0.33sec as their criterion interval. At present, it seems that any choice is purely arbitrary, yet the interval decided upon may well yield different strengths

of response rate - delay relationships. Further, Henton and Iversen (1978) assign delays of greater than 1 sec an equal status. Presumably this is because they were monitoring several behaviours, rather than just lever pressing. It is by no means clear from their analysis, however, what the effect on a behaviour might be if it is separated from the reinforcer by 2 or more other behaviours (i.e., greater temporal delays).

Finally, some of the data presented in experiments V and VI appear to conflict with Henton and Iversen's (1978) theory. In the event recordings presented in Chapter 8, an example of a response-reinforcer contiguity which was not followed by an increase in the probability of response emission was shown (Rat 88). Although such occurrences were rare, it is not clear why they should ever occur. In experiment VI, it was found that the mean PRP duration after a response-reinforcer contiguity was significantly shorter than after a response-reinforcer delay. This finding supports Henton and Iversen's (1978) position. The ranges of PRP durations, however, overlapped. This indicates that there were cases in which a response-reinforcer delay was followed by a shorter PRP than followed a response-reinforcer contiguity. To the extent that PRP duration is an index of response-emission probability on aperiodic schedules, it seems that response probability can be higher after a delay of reinforcement than after immediate reinforcement. It would seem that factors in addition to response-reinforcer contiguities can influence the probability of response

emission on VT schedules.

It was proposed in Chapter 8 that the pattern of responding was probably of greater significance than episodes of single-response-reinforcer contiguities. The response pattern will have been induced by the prior response-dependent reinforcement schedule. This is a critical point for Henton and Iversen (1978) because their view implies that the baseline schedule is largely irrelevant with respect to response persistence under a VT schedule. Although there is some evidence that response-independent schedules can control their own pattern of responding (Zeiler, 1968), the bulk of research indicates that the prior response-dependent schedule is a more potent variable (e.g., Alleman and Zeiler, 1974; Edwards et al, 1970; Franks and Lattal, 1976). The data from experiment II also supports the latter view - at least that from Rats 1 and 2. The argument may hinge upon how response patterning is measured. Cumulative recordings may not be the most sensitive method (because of their slow time-base). When IRT measures are used, it becomes clear that VT schedules can effect subtle changes on response patterning which may not be obvious on a cumulative record (see Shimp, 1975). The VT reinforcers, however, can only work on the IRT distributions which the baseline schedule has produced. To the extent that VT reinforcers can intercept IRT distributions which are different from those induced during the baseline so the VT schedule will change the pattern of responding. There may be occasions, however, where the

animal responds in such a way that there is little variation in the IRTs which are emitted (e.g., experiment II). In such cases, control by the VT schedule may take a large number of sessions to be achieved. There is the possibility that response maintenance during a VT schedule will depend upon the interaction between the pattern of responding and the VT reinforcers rather than that between single response instances and reinforcement.

The latter proposal has implications for the dimensions along which behaviour should be measured. The data from the present experiments once more require a consideration of a central issue in operant conditioning research - this issue is the response-unit problem (Schoenfeld and Farmer, 1970).

10.5 The response-unit problem and response-independent reinforcement.

Although the definition of a designated operant poses few problems (the definition is usually limited by the mechanical constraints of the manipulandum), defining 'other behaviour' may be more difficult (Schoenfeld and Farmer, 1970). Even when some criteria are outlined (e.g., temporal or topographical) a residual issue is how to aggregate behaviours so that functional and dynamic relations between behaviour and environmental events (e.g., reinforcers) can be demonstrated. It is on this latter issue that the discussion will focus initially.

Traditionally in operant conditioning, the type of aggregate

measure used has been the rate of responding metric. This custom has also been adopted by researchers into response-independent reinforcement. In the experiments reported here, the same measure has been used, although, for the most part, rates of responding during the VT schedules have been normalized so that comparisons across animals and conditions could be made. One problem with the response rate measure is that it is molar (Baum, 1973), i.e., a molar measure is being used to describe differences which may have their origin at the local level (e.g., Lachter, 1971; Lachter et al, 1971). Although it is possible to use this measure to describe local differences, this has rarely been done in studies of response-independent reinforcement (see, however, Lattal, 1972).

The response rate measure has been critisized by both molar and molecular theorists as being insensitive to schedule contingencies (Pear and Rector, 1979; Wearden and Burgess, 1982; Wheatley and Engberg, 1978). The limitations of this measure have led molar theorists to suggest that it might be replaced by a time allocation measure while molecular theorists have suggested using the IRT measure as an adjunct to the response rate measure.

10.5.1. Time allocation and response-independent reinforcement.

This measure has, until recently, only been used in the context of response-independent reinforcement when a discrete response such as a keypeck or a lever press was not

the operant (Brownstein and Pliskoff, 1968). Its possible utility in this area, however, can be seen in both some of the data from experiment V and in a recent experiment conducted by Burgess and Harland (1984). In experiment V, event recordings of Rat 83's behaviour revealed that lever pressing was replaced by tray entry behaviour. The number of tray entry responses, however, were lower during the VT sessions relative to the baseline; indeed there were some sessions in which the rat entered the tray on fewer occasions than there were reinforcer deliveries. The event recordings indicated that this was because the rat remained in the tray during the delivery of a succession of food pellets. Under these sort of circumstances, a time allocation measure would have yielded more accurate data than a simple response rate measure. This proposition is supported by the results from a recent experiment reported by Burgess and Harland (1984). They trained rats to hold down a lever for 8 sec. The animals were then transferred to a matched VT schedule. Both rate of lever pressing and lever press durations were monitored. These measures were then related to the proportion of reinforcers contiguous with a response for the response rate data and to proportion of reinforcers contiguous with 'other behaviour' for the response duration measure. The correlations which emerged for the response rate measure were 0.05, 0.65 and 0.79 for the three rats studied. The last two correlations are significant at the 5% level. The corresponding correlations for the lever press duration response were -0.84, -0.91 and -0.96 all of which are significant at the 1% level. The

time allocation measure therefore was a much more sensitive index of behaviour-environment interactions than was the response rate measure. Notice, here, that time allocation was used in a molecular fashion. It is possible that had a time allocation measure been used in the experiments reported here even stronger relationships between delay of reinforcement and lever pressing might have emerged. It could be objected that the time allocation measure was more closely related to the temporal interval between the response and reinforcer than was the response rate measure in the experiment reported by Burgess and Harland (1984) because of the topography of the response initially reinforced. This is a similar sort of objection that was raised concerning the utility of the IRT measure in experiment IV. Whether the time allocation measure would show the same generality as the IRT measure (see experiment VI), is a question which has still be answered but there are no a priori reasons to believe that it would not (see Pear and Rector, 1979).

10.5.2. IRT theory and response-independent reinforcement

To some extent the IRT measure is a molecular equivalent of the molar time allocation measure - i.e., the longer the IRTs the less time the organism allocates to emitting the designated response. The IRT measure also provides details concerning the relative strengths of both R and $\not R$ in the behaviour stream. In two of the experiments reported here an IRT analysis was presented. The data from experiment VI are of particular interest. In that experiment a highly

significant relationship between reinforced and overall IRTs was demonstrated during the VT schedule despite the lack of any IRT contingency.

IRT theory departs from response competition theory in terms of the nature of the response which is reinforced in operant conditioning schedules. Whereas the response competition view stresses the contiguity between the most recently occurring behaviour and reinforcement, IRT theory maintains that a pattern of behaviour is reinforced (Shimp, 1975). In a more recent formulation, Shimp has noted that ". . . temporal contiguity of observed events is replaced here by temporal contiguity of memory codes of observed events occurring within a short-term memory span." (Shimp, 1978, p43). How might IRT theory be applied in the present context? Suppose that a reinforcer is contiguous with a discrete lever press response which is part of a burst of responding. Both response competition theory and IRT theory would predict that the probability of emission of a response during the next IRI would be high. In contrast to this situation, suppose that a reinforcer is contiguous with a response which is not part of a response burst, i.e., is separated from a previous response instance by some seconds. Under these circumstances, response competition theory would make the same prediction. IRT theory, however, would not. Instead the relevant variable would be the duration of the IRT. It would be that duration which would be more likely to occur. An example of each of these cases was presented in the event records of Rat 88's behaviour in experiment V.

It was noted there that when the IRT duration was relatively long, then the probability of a response emission was somewhat lower than where the reinforcer intercepted a response burst. It was also noted that occasional response-reinforcer contiguities had little or no effect on Rat 89's performance during the first exposure to VT reinforcement.

There are other data which would also support IRT theory rather than a response competition view. For example, Lattal and Ziegler (1982) have noted that sometimes a very short delay of reinforcement (0.5 sec) was associated with an increase in response rate relative to that associated with an immediate reinforcement schedule. The change in rate, however, was dependent upon the IRTs which were reinforced.

In a number of the experiments reported here, an apparatus malfunction in the form of the delivery of 'double reinforcers' took place. Generally, these episodes were correlated with response decrement. Response competition theory can easily explain this finding because no responses usually interceded between the delivery of the first and second reinforcers. There were occasions, however, when double reinforcers were dispensed yet the rate of responding during those particular sessions was above that which prevailed during the baseline (e.g., Rat 81, experiment V). This sort of finding is potentially embarrassing for the response competition view, although it is possible that these episodes of a reinforcer intercepting R were

overshadowed by response-reinforcer contiguities elsewhere during the session.

Exactly why 'double reinforcers' have such a marked effect on response maintenance during the VT schedule is not known. One possibility, however, is that their effect mimics a similar sort of phenomenon which has been examined within the classical conditioning field. The phenomenon being to referred to is that known as 'blocking'. The typical experimental paradigm in which the effect is produced is as follows. An organism is exposed to CS - US pairings until asymptotic responding is reached. The organism is then exposed to a compound stimulus comprised of the original CS and a new CS, the whole compound being paired with a reinforcer of the same magnitude as had been used during the first phase. Finally, the added CS is presented on its own during test trials. The typical finding here is that the new CS acquires less associative (or response-eliciting) strength than it would have had the first phase had been omitted. Essentially, then, the response-controlling properties of the new CS have been blocked by the response-eliciting strength acquired by the original CS during the first phase of the experiment (Kamin, 1969). Researchers in this field have attempted to specify the conditions under which blocking will be attenuated (e.g., Rescorla and Wagner, 1972). A preparation of particular interest in this context is the post-trial surprise paradigm. In one variant of this, a second reinforcer is added a short time after the first US during the compound conditioning phase. Under this

arrangement, the normal blocking effect is attenuated (Dickinson and Mackintosh, 1979; Kamin, 1969). According to researchers in this field, the added US 'surprises' the organism. Surprise either causes the animal to scan its memory for events just past (Kamin, 1969) or the salience of the added CS to be enhanced (Mackintosh, Bygrave and Picton, 1977). In the present context, the double reinforcer may surprise the organism and make the behaviour occurring just prior to the first reinforcer more salient. Thus, if short IRTs had been emitted prior to the delivery of the first reinforcer, then these would be likely to be repeated. Alternatively, if the organism had just emitted a relatively long IRT or was in the process of emitting a long IRT, then response decrement would be more likely to occur. IRT theory then, is in the position of being able to make differential predictions in this context, while the response competition view could find some of these potential outcomes difficult to explain. In order to evaluate the proposal, access to data in the form of sequential IRTs would be required. Unfortunately, that kind of data is lacking and therefore this account must remain speculative.

Because the IRT measure is a time-based one, it is open to the same criticism which was made above concerning the spatial position of the organism at the time of reinforcement. Pear et al (1982) have noted that IRTs of the same duration often encompass quite different behaviours. Exactly how critical this is has yet to be determined. To the extent that reinforcement schedules

induce stereotyped patterns of behaviour (Schwartz, 1981) and the relationship between reinforced and emitted IRTs remains high, however, this sort of observation may not be as damaging to IRT theory as one might suppose.

10.6 Conclusion

Overall, there seems little reason to make recourse to the discrimination of response-reinforcer dependencies in explaining the differences in responding under response-dependent and response-independent reinforcement conditions, as correlation theory demands. Where response-dependent and response-independent reinforcement schedules differ is in terms of the response-reinforcer delays which they permit. There is a great deal of evidence to suggest that response rate during both response-dependent and response-independent reinforcement schedules is inversely related to obtained delays of reinforcement (see experiments IV, V and VI; Sizemore and Lattal, 1977; Weill, 1984). Evidence also exists which demonstrates that animals are sensitive to even small changes in response-reinforcer contiguities (Henton and Iversen, 1978; Nussear and Lattal, 1983). The results from the present experiments indicate that response rate during VT schedules is a function of the interaction between the pattern of responding engendered by the baseline response-dependent reinforcement schedule and the reinforcement delays experienced by the organism during the VT schedule. Specifically, baseline schedules which either allowed more than one response class to be contiguous with the reinforcer or demanded the emission of two response classes in a specified order tended to be associated with greater resistance to response-independent reinforcement relative to conventional immediate reinforcement schedules (i.e., VR, VI, FR and FI). The effect of the schedule

manipulation, however, was moderated by the IRT-reinforcer contiguities which occurred during the VT phase. Therefore, although an analysis framed in terms of discrete response-reinforcer contiguities may be able to explain many of the results, it is faced with some anomalous findings. A liberalized version of contiguity theory which is framed in terms of IRT-reinforcer contiguities probably holds more promise (Peele et al, 1984).

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